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DEPARTMENT OF THE INTERIOR
ALBERT B. FALL, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Bulletin 727

POTASH IN THE GREENSANDS OF NEW JERSEY

BY

GEORGE ROGERS MANSFIELD

Work done in cooperation with the Department of Conservation
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ABSTRACT OF REPORT.

The greensand marl belt of New Jersey extends across the State from the vicinity of Sandy Hook at the northeast to Delaware River near Salem at the southwest, a distance of about 100 miles. It is crossed at many places by railroads and by streams that flow into Delaware River.

The potash in the greensand marl occurs chiefly in the mineral glauconite, which is essentially a hydrous silicate of ferric iron and potassium. Nearly all the Cretaceous formations contain glauconite, but only three contain sufficient amounts to be considered commercially important, though in some others it is locally abundant. These three are the Navesink (the lowermost), Hornerstown, and Manasquan marls, which are described respectively as 25 to 40, 30, and 25 feet thick. The marl beds, which form part of the Coastal Plain strata, strike about N. 55° E. and dip about 33 feet to the mile southeast, but there are some variations. The gently inclined and poorly consolidated beds that compose the marl are beveled by erosion and covered to a greater or less extent by later deposits.

Five type areas were explored by borings and made the basis of specific estimates. These were at Salem and Woodstown, in Salem County; Sewell, in Gloucester County; Somerdale, in Camden County; and Elmwood Road, in Burlington County. The data gathered from borings were supplemented by well data, both published and unpublished, and by field data on file in the office of the State department of conservation and development.

It is conservatively estimated that the New Jersey greensands contain 256,953,000 short tons of potash (K_2O) that could be mined by open-pit methods. At the rate of importation for the five years preceding the World War, including 1914, this quantity could supply the needs of the United States for nearly 1,000 years. Should it ever become practicable to use underground methods of mining, the available quantity of potash would be enormously increased.

The lime sand in probable commercial thickness is exposed or has been recognized in wells as far north as Wrightstown.

Four companies have undertaken to produce or utilize the potash from New Jersey greensand. Small quantities of potash have been produced and marketed by some of these companies, but none are now producing. The potash industry of the United States was dealt a

severe blow by the conditions arising after the armistice was declared. It seems probable, however, that some of the large developments will survive. Whether or not greensand may have a place in the American potash industry will depend on how well the greensand operators may be able to compete not only with German producers but also with American producers of potash from other sources.

Recent experiments indicate that the potash in greensand is promptly available to meet the needs of many and perhaps most farm crops.

Composite samples, so prepared as to represent the principal beds of commercial thickness at each of the localities drilled, were washed and the residues magnetically separated and sized. A variety of determinations upon original or prepared samples were also made in the chemical laboratory of the United States Geological Survey. The results of these separations and determinations are discussed both in their relation to the recovery of potash from greensand and in their bearing on the origin of glauconite.

POTASH IN THE GREENSANDS OF NEW JERSEY.

By George Rogers Mansfield.

INTRODUCTION.

PURPOSE AND SCOPE OF INVESTIGATION.

The work on which this report is based was begun in the fall of 1918 as a part of the systematic search for potash conducted by the United States Geological Survey since 1910.

The New Jersey greensand marls have long been known to contain small amounts of potash, lime, and phosphate. For more than 100 years they were dug and marketed as fertilizer, and in the late sixties the annual amount so used aggregated nearly 1,000,000 tons.[1] With the introduction of prepared fertilizers the marl industry died away, but small amounts of greensand are still dug and used here and there.

It has been considered impracticable to extract commercially the potash from greensand because of the relatively insoluble character of the mineral in which the potash is locked up. Of late years, however, there has been considerable experimentation in processes of extracting potash from silicate minerals, and the New Jersey greensands, which are silicates, have attracted attention because of their accessibility, abundance, and relative ease of mining. The scarcity of potash resulting from the shutting out of German supplies during the World War gave impetus to these experiments and permitted hope of the establishment of a potash industry in the United States in which the New Jersey greensands might be an important factor.

Much general information about the greensands was available through the published reports of the Geological Survey of New Jersey and of the United States Geological Survey and from other sources. The greensand beds had been mapped and described in considerable detail. There was, however, little specific knowledge regarding the quantity, thickness, and character of the deposit and the accompanying overburden at any particular place. The purpose of the work, therefore, was to procure data sufficient to permit estimates of the tonnage of potash in certain areas that are

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[1] Cook, G. H., Geology of New Jersey, p. 461, 1868.

favorably situated for commercial enterprise, and to determine the nature and thickness of the overburden in those areas.

The investigation was begun at the instance of the United States Geological Survey, but the New Jersey Department of Conservation and Development cooperated in it, with the understanding that the cost of the work should be divided as nearly equally as possible between the State and the Federal Survey. The money actually expended in field work amounted to $2,884, of which the State paid $1,550 and the Survey $1,334. The Survey, however, furnished the time of the field geologist and the numerous chemical analyses and assumed the other expenses incidental to the preparation and publication of the report.

ACKNOWLEDGMENTS.

The writer desires to express his thanks to Dr. Henry B. Kümmel, State geologist, and his staff for much helpful information and for the use of unpublished data, including field notes, manuscript maps, and well records. Several days were spent at his office in the study of this material. Dr. Kümmel accompanied the writer on several trips to different parts of the marl belt, one of which was made possible by the kindness of Prof. Gilbert Van Ingen, of Princeton University, who gave his time and the use of his automobile. Dr. M. W. Twitchell, assistant State geologist, went over some 500 cards in search of analyses that might bear on potash exploration, hunted out numerous well records, and kindly permitted the use of his unpublished manuscript on the water resources of the State.

The numerous analyses embodied in this report were made in the laboratories of the Geological Survey, mostly by R. K. Bailey, though some were made by Chase Palmer and E. T. Erickson. George Steiger, chief chemist, made many helpful suggestions, and W. B. Hicks, of the laboratory staff, visited parts of the field with the writer. E. S. Larsen, jr., examined a number of thin sections and made helpful suggestions. Hoyt S. Gale, geologist in charge of the potash investigations of the Survey, Mr. Hicks, and Miss M. R. Nourse have contributed valuable suggestions and criticism.

The writer is indebted to the following persons for permission to drill on their land: Messrs. Louis A. Fogg, T. R. Miller, and Lucius Hires, of Salem; Mr. Isaac K. Lippincott, of Woodstown; Mr. J. C. Voorhies, of Woodbury, secretary of the West Jersey Marl & Transportation Co. (owner of property at Sewell); Mr. Thomas McMichael, of Somerdale (Laurel Springs post office); Mr. Alfonso Fusco, of Elmwood Road; Dr. E. W. Taylor, of Germantown, Pa. (owner of property near Vincentown); Dr. J. Clifford Haines, of Vincentown; the Norcross & Edmunds Co., of Birmingham; Mr. W. G. Taylor, of Pemberton; Mr. Alfred Cox, of Juliustown; and Miss Rebecca

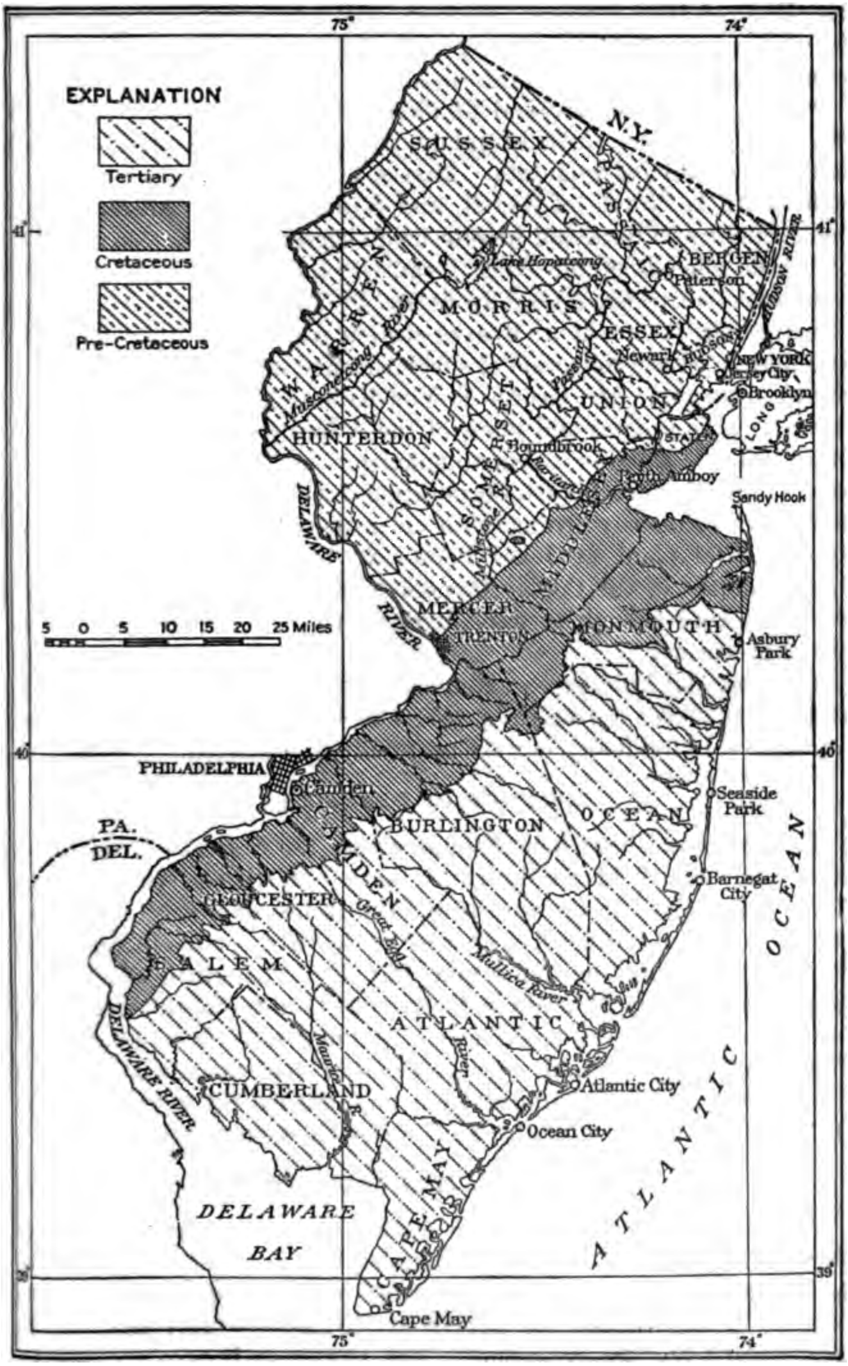


FIGURE 1.—Geologic index map of New Jersey, showing the general distribution of the pre-Cretaceous, Cretaceous, and post-Cretaceous formations.

Hopkins, of Hornerstown. Unfortunately time was not sufficient for drilling at all these places. Mr. William T. Hoffman, of Birmingham, furnished useful information.

Messrs. Oren Conover and Chalkley Haines, of Woodstown, and William B. Cooper, A. G. Dunphey, and Samuel R. Cooper, of Marlton, furnished local well data. Messrs. C. C. Holladay, of Harmersville, John L. North, of Sewell, and S. J. Taylor, of Mount Holly, contributed well data and helpful field suggestions.

To the officials of the R. S. Ryan Co. the writer is indebted for numerous courtesies, especially to Mr. F. Tschirner, who conducted him through the plant at Reeves station while it was in operation and permitted the collection of specimens and other data on the company's property. Mr. George F. Von Kolnitz kindly furnished data regarding the process and plans of the Atlantic Potash Corporation. Messrs. T. C. Meadows, general manager, and George Hafer, engineer of the Eastern Potash Corporation, furnished valuable information and courteously arranged for an inspection of the corporation's experimental plant at Jones Point, N. Y. Mr. David L. Frank, vice president of the Coplay Cement Manufacturing Co., of Coplay, Pa., was kind enough to explain the company's experience in the use of greensand.

The personal kindnesses extended to the writer by the residents at different places during the progress of the work are too numerous to mention individually but are gratefully appreciated.

LOCATION OF DEPOSITS.

The greensand-marl belt extends across the State of New Jersey from the vicinity of Sandy Hook, at the northeast, to Delaware River near Salem at the southwest, a distance of nearly 100 miles. It lies along the southeastern border of the broad strip of Cretaceous deposits shown on the index map (fig. 1). The width of the belt ranges from nearly 14 miles in Monmouth County, at the northeast, to 1 mile or less in parts of Gloucester County, toward the southwest. The detailed distribution of the greensand marl is shown in Plates I to III (in pocket), compiled from unpublished maps prepared by G. N. Knapp, formerly of the New Jersey Geological Survey.

TRANSPORTATION FACILITIES.

The railroads that connect the seashore resorts along the coast of New Jersey with New York, Philadelphia, and other cities (see fig. 1) cross the marl belt at a number of places and could supply suitable transportation for potash and other products that might be derived from the greensand. The marl belt is also crossed by numerous streams which flow into Delaware River, some of which, such as Mantua, Rancocas, and Crosswicks creeks, are large enough to be utilized, at least in part, for transportation. Companies pro-

posing to establish plants for utilizing greensand would do well to consider the possibilities of water transportation in their estimates of cost.

GENERAL FEATURES OF THE DEPOSITS.

CHARACTER

The potash occurs chiefly in the mineral glauconite, which constitutes the green grains of the so-called marl. The term "marl" as used in New Jersey includes a variety of materials. Thus we have greensand or glauconitic marl, clay marl, sand marl, and lime sand or lime-sand marl. Ordinarily greensand is implied when the term is used, but one or more of the other types is frequently included, especially in well records, so that it is difficult or impossible to make any detailed stratigraphic interpretation of many of these records.

The greensand beds are in general unconsolidated deposits consisting of variable proportions of glauconite grains, clay, quartz, and a variety of small fragments of other minerals. A more detailed description of these constituents and their relative proportions is given in the sections on mechanical analyses of greensand, chemical analyses, and nature and origin of glauconite. (See pp. 116–133, 138–142.)

The glauconite imparts a greenish color to beds in which it occurs, and beds consisting largely of dark-green or black glauconite appear nearly black when freshly opened. The claylike constituents, where abundant, impart color to the beds. Thus some are light green, but others are dark green, drab, or chocolate-brown, although in each bed the glauconite grains are generally dark-green or nearly black. Likewise where quartz grains are abundant the beds have a color resembling that of a mixture of pepper and salt. There is much similarity of appearance between masses of the black phase of the greensand and masses of disintegrated material from beds of black or brown oolitic phosphate rock in the Idaho field.

The glauconite grains range in size from less than one one-hundredth to more than one-twentieth of an inch. Some of the larger grains resemble casts of shells of Foraminifera. Many appear to be more or less irregular aggregates of small rounded masses, and others seem to be small nodules irregularly cracked and recemented. The smaller sizes are worn and have evidently been transported to their present positions from neighboring or other sources. (See Pl. IV.) Clay with grains of glauconite forms nodules and casts of shells. Nodules containing more or less pyrite are present here and there, and locally tiny grains of pyrite occur. Nodules of phosphate of lime are also present.

Marine shells and other marine fossils representing a considerable fauna have been found in the greensand beds. The shells are scat-

tered to some extent through the mass of the greensand, but there are two beds in which they are very abundant and which serve as horizon markers. These are respectively the *Belemnitella*-bearing bed, at the base of the Navesink marl, and the *Terebratula*-bearing bed, at the top of the Hornerstown marl. These formations are described on pages 10 and 11.

The bedding of the greensand, so far as observed, seems relatively uniform and free from cross-bedding, though locally streaks of differently colored clay occur in a single set of beds. For example, at Sewell, where greensand is dug, the upper 2 feet of chocolate-colored material at the top of the so-called chocolate marl is streaked with green material of similar texture. At Somerdale a bed of drab material about 18 feet thick shows more or less streaking of gray and green throughout.

STRIKE, DIP, AND THICKNESS.

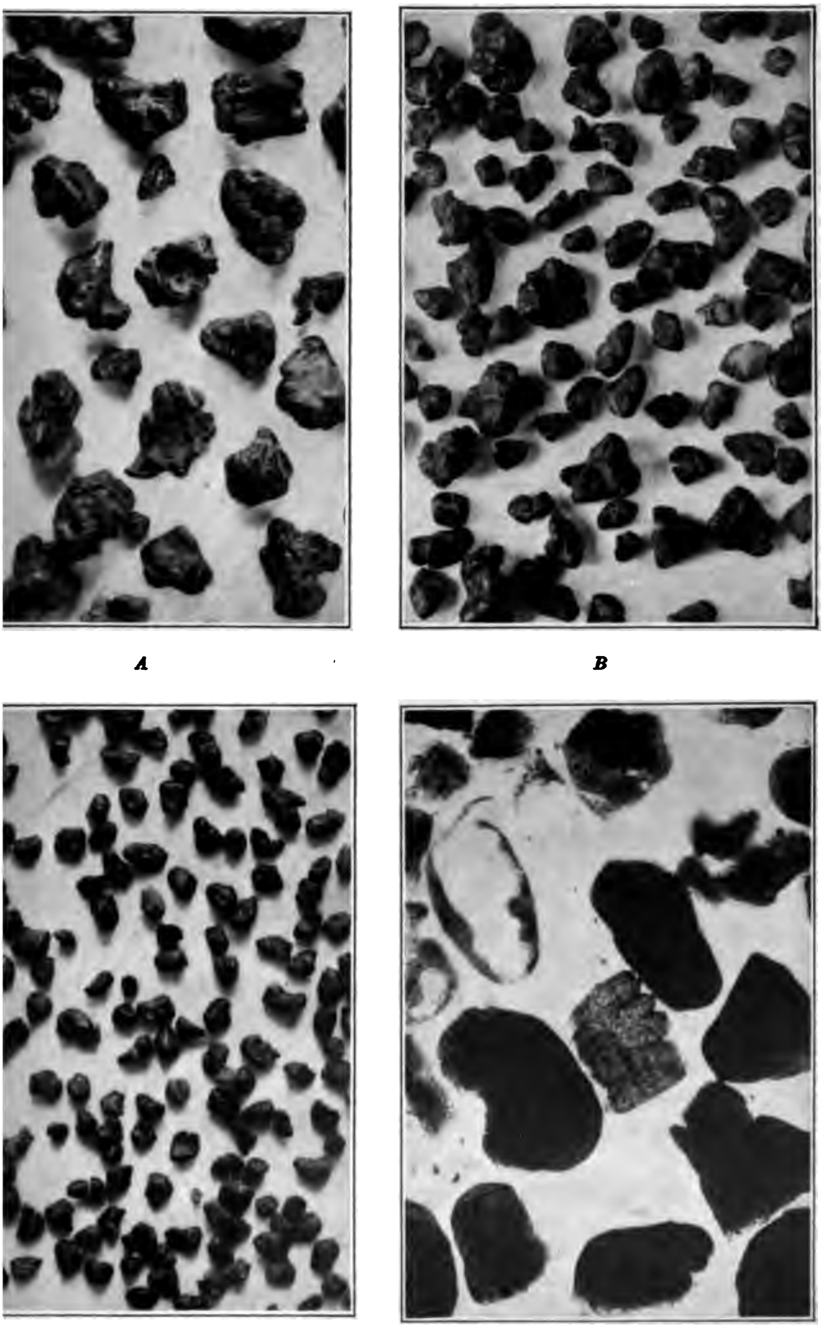
According to previous reports the average strike of the greensand beds is about N. 55° E. The dip is estimated by Knapp at 33 feet to the mile, with some variations, for a distance of 15 miles back from the outcrop; at greater distances it apparently steepens. The gentle inclination of the beds and the erosion they have suffered cause them to wedge out along the northwest margin of the marl belt. The thickness therefore ranges from a few inches along the northwest margin to nearly 50 feet in places along the southeast margin. Variations in thickness along the strike are due to local erosion or to differences in conditions of deposition.

LOCAL NAMES.

The greensand beds at some localities show sufficient variation in color and constituents to give rise to useful local names. Thus at Sewell three types are recognized—gray or bank marl, green marl, and chocolate marl. These names are applied to beds of commercial thickness, which are traceable through a considerable area. At Somerdale a small deposit consisting chiefly of quartz grains, iron oxide, clay, and a little glauconite is called red marl.

MODE OF OCCURRENCE.

The marl belt is part of the New Jersey Coastal Plain, which in turn is in the northern part of the great Coastal Plain that extends along the Atlantic and Gulf seaboards. Glauconite deposits occur in greater or less abundance in other parts of this plain and indeed in some of the older geologic formations not now associated with coastal plains, notably in the Cambrian sandstones of parts of the West and Southwest. According to present knowledge, however, the glauconite beds of New Jersey are probably richer in potash than those elsewhere.



A *B*

C *D*

MICROPHOTOGRAPHS OF GLAUCONITE.

Grains between 1/10 and 1/20 inch in diameter, the maximum size. × 10, showing characteristic apes; *B*, grains between 1/20 and 1/40 inch, × 10, shapes similar to those in A but more worn; , grains between 1/40 and 1/60 inch, × 10, shapes similar to those in *A* and *B* but considerably ore worn; *D*, thin section of glauconite grains between 1/40 and 1/60 inch, × 50, showing the ky to granular structure of the glauconite and in the center a supposed crystal with rude cleavage.

The Coastal Plain in New Jersey has long been cited as an example of the belted type, with inner lowland, in-facing slope, out-facing slope, and outer lowland, caused by the erosion of gently dipping strata of somewhat unequal degrees of coherence or hardness and by the development of drainage upon those strata. The marl beds lie near or at the top of the in-facing slope and thus relatively near Delaware River, which occupies much of the inner lowland, and their drainage in general flows toward that lowland, producing the favorable conditions for water transportation previously noted.

GLAUCONITE-BEARING AND ASSOCIATED FORMATIONS.

Age and general sequence.—The glauconite beds of New Jersey, with one exception, are of Cretaceous age. Glauconite occurs locally, however, in some of the overlying Tertiary and Quaternary beds as a result of the erosion and redeposition of Cretaceous material. At some places, as for example, at Somerdale, about 9 miles southeast of Camden, these reworked glauconite beds overlie beds of Cretaceous greensand and may readily be mistaken for them. Closer inspection of the reworked material reveals pebbles scattered through its mass and usually a more or less well-defined layer of pebbles at its base. The Cretaceous formations are described below and are shown with the overlying Tertiary formations in the accompanying table.[2]

Cretaceous and later formations in Coastal Plain region of New Jersey.

System.	Series.	Formation.	Thickness (feet).
Quaternary.	Recent.	Beach sand and gravel, marsh deposits, and alluvium.	
	Pleistocene.	Cape May formation	0-20
		Pensauken formation	0-20
		Bridgeton formation	0-30
Tertiary.	Pliocene (?).	Beacon Hill gravel	
		Unconformity?	
	Miocene (?).	Cohansey sand	100-250
		Unconformity	
	Miocene.	Kirkwood formation	100
		Unconformity	
	Eocene.	Shark River marl	11
		Unconformity	
Cretaceous.	Upper Cretaceous.	Manasquan marl	25
		Rancocas group:	
		Vincentown sand	25-70
		Hornerstown marl	30
		Monmouth group:	
		Redbank sand with Tinton sand member (10-20 feet) at top.	0-10
		Navesink marl	25-40
		Mount Laurel sand	5-60
		Matawan group:	
		Wenonah sand	20-35
		Marshalltown formation	30-35
		Englishtown sand	20-100
		Woodbury clay	50
		Merchantville clay	60
		Magothy formation	25-175
		Unconformity	
		Raritan formation	150-250
		Great unconformity.	

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[2] Table and descriptions compiled chiefly from New Jersey Geol. Survey Bull. 14, 1915; U. S. Geol. Survey Geol. Atlas, Philadelphia folio (No. 162), 1909, and Trenton folio (No. 167), 1909.

Raritan formation.—The beds of the Raritan formation are of continental origin and extremely variable, consisting chiefly of light-colored sands and clays. Some of the clays are highly refractory. Clays are more abundant in the lower half of the formation and sands in the upper half. Some of the sands are water-bearing. As the surface on which the beds were laid down was irregular the thickness of the formation is variable, ranging from 150 to 250 feet at the outcrop but increasing toward the southeast to more than 500 feet, as shown by well borings. Its dip is somewhat steeper than that of the marl beds, ranging from 40 to 50 feet to the mile toward the southeast. Animal remains are scarce, but plant remains are numerous, and some of the genera and species are closely related to modern forms. The formation rests in places on Triassic rocks, but from the vicinity of Trenton southward it rests on ancient crystalline rocks of Paleozoic or pre-Paleozoic age.

Magothy formation.—The Magothy formation is partly of continental and partly of marine origin and includes beds of sand and clay, some of which are utilized, with glauconite beds toward the top. On the shores of Raritan Bay the formation is 175 feet thick, but its thickness diminishes toward the southwest and along Delaware River is only 25 to 30 feet. Plant remains of a somewhat more recent aspect than those of the Raritan are numerous, and 43 species of marine fossils have been recognized. The Magothy lies unconformably upon the Raritan, but the discordance is not great and probably indicates only a slight land movement. The Raritan and Magothy formations are the chief sources of clay in the great center of the industry about the lower Raritan River and Raritan Bay.

Merchantville clay.—The Merchantville formation is a black glauconitic, micaceous clay about 60 feet thick, which is generally greasy in appearance and of massive structure and weathers to an indurated brown earth. It is conformable with the beds both above and below and contains numerous marine fossils, the most characteristic species of which are rare or absent in adjacent strata. The Merchantville clay represents the lower part of the "Crosswicks clay" of Clark, forms the base of the "Clay-Marl series" of Cook, and is the lowest of the five formations composing the Matawan group of New Jersey. In Maryland the Matawan deposits are not subdivided and are called the Matawan formation. The Merchantville clay is utilized with the overlying Woodbury clay in the manufacture of brick and fireproofing material along the south shore of Raritan Bay in Monmouth County, in southern Middlesex and Mercer counties, and in western Burlington and Camden counties.

Woodbury clay.—The Woodbury clay is a black nonglauconitic jointed clay about 50 feet thick which weathers to a light chocolate color and when dry breaks into innumerable blocks, many of them showing

curved surfaces of fracture. Some 95 species of marine fossils have been recognized, and these are more closely related to the Magothy species than to those of the underlying Merchantville. The beds are conformable with those above and below. They represent the upper part of the "Crosswicks clay" of Clark and are part of Cook's "Clay-Marl series." The formation is one of the five formations of the Matawan group.

Englishtown sand.—The Englishtown is a conspicuous bed of white or yellow quartz sand, slightly micaceous and sparingly glauconitic. Locally it has been cemented in part by iron oxide into massive stone. South of Woodbury, in Gloucester County, it contains local beds of clay that are utilized for making brick. In Monmouth County and to some extent farther south the Englishtown sand is an important water-bearing bed. It decreases in thickness from 100 feet near Atlantic Highlands to less than 20 feet in the southern part of the State. It represents the lower part of the "Hazlet sands" of Clark and forms part of Cook's "Clay-Marl series." It was formerly called the "Columbus sand" and is one of the formations of the Matawan group. It is not known to contain fossils.

Marshalltown formation.—The Marshalltown formation ranges from a black sandy clay to a clayey greensand marl. Locally it contains many fossils, its characteristic species being in part recurrent forms from the Merchantville and in part forms that occur in a higher formation, though absent or inconspicuous in immediately succeeding beds. The formation is 30 to 35 feet thick. It is a portion of the "laminated sands" that formed the upper part of the "Clay-Marl series" of Cook, although in the southwestern part of the State he referred these beds to the Navesink marl. It was included in Clark's "Hazlet sands" and is one of the formations of the Matawan group. In parts of Burlington and Camden counties beds of clay in the Marshalltown formation are used for the manufacture of brick. The greensand of the formation is locally abundant and has been dug for fertilizer.

Wenonah and Mount Laurel sands.—Above the Marshalltown formation there is a considerable thickness of sand regarding which there has been some difference of opinion. The terms Wenonah and Mount Laurel have both been applied to it in whole or in part. The sand is of rather uniform character, though the lower part (Wenonah) is generally a fine micaceous sand, and the upper part (Mount Laurel) is coarser and contains considerable glauconite. These sands contain considerable water in the southern and central parts of the State, where they are about 80 feet thick, but toward the northeast they decrease both in thickness and in permeability.

The fossils of the Wenonah are largely recurrent from the Woodbury, and the same forms recur higher in the Redbank. The fossils of the Mount Laurel are identical with those of the Navesink and are closely allied to those of the Marshalltown. A noteworthy form that occurs in the Mount Laurel and extends into the basal bed of the Navesink is the pencil-shaped *Belemnitella americana.* The combined thickness of the Wenonah and Mount Laurel formations is 40 to 80 feet. The Mount Laurel is very thin at Atlantic Highlands, where it was called "Sand-marl" by Cook, but increases much in thickness toward the southwest. The Wenonah sand is the highest formation of the Matawan group; the Mount Laurel is the basal formation of the overlying Monmouth group.

Navesink marl.—The Navesink marl consists of greensand marl mixed with varying amounts of quartz sand and fine earth containing much calcium carbonate in a powdery state. Where purest the marl has a dark-green to bluish-black color. The upper part of the bed contains progressively less greensand and is more clayey. The fauna is large, comprising 121 species, according to Weller, and is allied with that of the Marshalltown and Merchantville beds; the characteristic forms of the Magothy, Woodbury, and Wenonah are absent. The basal bed of the Navesink at many localities, as at Mullica Hill, is a shell bed several feet thick (see Pl. VI, *B*), in which, as in the Mount Laurel sand, the pencil-shaped *Belemnitella americana* is conspicuous. Another characteristic feature of this bed is the occurrence of smoothed or polished gravel grains, chiefly quartz, about one-eighth of an inch in diameter, for which Knapp suggested the name "rice gravel." The formation has a maximum thickness of about 40 feet, which diminishes southward to 25 feet or less. It corresponds in general to Cook's "Lower marl," although some beds referred by him to the "Lower marl" have proved to be Marshalltown. It rests conformably upon the beds below and grades upward into the Redbank sand or, where that is absent, into the Hornerstown marl. The Navesink is the middle formation of the Monmouth group. In Maryland the Monmouth deposits are not subdivided and are called Monmouth formation. The Navesink marl has been extensively dug for fertilizer throughout much of the marl belt.

Redbank sand, including Tinton sand member.—The Redbank beds consist for the most part of fairly coarse yellow and reddish-brown quartz sand, locally indurated by the infiltration of iron oxide. The lower beds are in many places somewhat clayey, and the fossils of the Redbank have been found mostly in the clayey layers. The fauna is a recurrence of Magothy, Woodbury, and Wenonah forms and differs in important respects from the Navesink fauna below. The Redbank sand has a maximum thickness of 100 feet in the north-

ern part of the Coastal Plain, where it is a valuable water-bearing formation, but thins out southwestward and disappears in the vicinity of Skyesville, in the northern part of Burlington County. It is the "Red sand" of Cook and earlier writers but does not include certain sands in the southern part of the State that were erroneously correlated by Cook with the "Red sand" of Monmouth County. With the Tinton sand member at the top it is the uppermost formation of the Monmouth group. The Tinton member consists of a bed of green indurated clayey and sandy glauconitic marl 10 to 20 feet thick in Monmouth County. Its fauna is more closely allied to that of the Navesink than to that of the Redbank and is characterized by large numbers of crustacean claws. It is Cook's "indurated green earth," regarded by him as part of the "Red sand."

Hornerstown marl.—The Hornerstown marl is a bed of glauconite with clay and sand, having a total thickness of 30 feet or less. It does not differ much in appearance from the Navesink, although where unweathered it may have a greener tinge. Its fauna, though meager, is different in essential characteristics from the fauna of all the underlying formations. A shell bed 4 to 7 feet thick at the top of the formation is a conspicuous feature at many localities. The brachiopod *Terebratula harlani*, which occurs in great numbers in the upper part of the shell bed, is perhaps the most distinctive fossil. At the north the formation rests with apparent conformity on the Tinton. Where that is absent it lies on the Redbank, and farther south, owing to the disappearance of the Redbank, it is continuous with the Navesink and not generally distinguished from it. It is conformably overlain by the Vincentown sand except where overlapped by Tertiary formations. It is the "Middle marl" of Cook and the "Sewell marl" of Clark and forms the lower formation of the Rancocas group, the Vincentown sand being the upper formation. In Maryland the Rancocas deposits are not divided and are called the Rancocas formation. The Hornerstown marl has been extensively dug and used as a fertilizer.

Vincentown sand.—The Vincentown sand presents two phases—(1) a calcareous or lime sand, more or less indurated and largely a mass of broken bryozoan, echinoid, coral, and other calcareous remains; (2) a glauconitic quartz sand. The two occur in alternating layers, although the lime sand is more common in the basal portion, particularly to the south, and the quartz sand predominates in Monmouth County. The fauna of the siliceous phase contains elements of the Hornerstown fauna in association with forms characteristic of the calcareous phase. The thickness of the formation ranges from 25 to 70 feet, but numerous well borings have shown that it thickens down the dip—that is, toward the southeast—as do most of the other formations. It rests conformably upon the Horners-

town marl and is overlain conformably by the Manasquan marl or overlapped by Tertiary beds. The Vincentown sand includes the "lime sand" and "yellow sand" of Cook, the former of which was included by him as a part of the Hornerstown ("Middle") marl, and is the upper formation of the Rancocas group. The formation contains much water throughout the length of the New Jersey Coastal Plain. The more calcareous beds have been used locally for building stone and for burning.

Manasquan marl.—The lower 13 to 17 feet of the Manasquan marl is, like the Hornerstown and Navesink marls, composed largely of glauconite together with sand and clay and has a green or greenish-gray color. The upper 8 to 12 feet is made up of very fine sand mixed with greenish-white clay. Piles of this material look like heaps of ashes, whence the name "ash marl." Fossils are not abundant or well preserved. The thickness of the formation is about 25 feet. It corresponds to the "green" and "ash" marls of Cook's "Upper marl bed" and is the youngest of the Cretaceous formations exposed in New Jersey. It rests conformably on the Vincentown and at most exposures is succeeded unconformably by Tertiary or Quaternary deposits, although locally it is overlain by a bluish marl of Eocene age (Shark River marl) without apparent unconformity. The Manasquan marl has been dug and extensively used as fertilizer.

Tertiary and Quaternary formations.—Aside from the local deposits of reworked material already mentioned the Shark River marl (Eocene) is the only post-Cretaceous formation that carries significant amounts of glauconite. The Shark River marl crops out only in a few small areas near Long Branch and Farmingdale, in Monmouth County. Its maximum thickness is only 11 feet, and though apparently conformable upon the Manasquan it is believed from well borings to overlap the Cretaceous. It has little commercial importance.

The succeeding formations are sufficiently described for the purposes of this report in the table on page 7. They constitute much of the overburden to be encountered in exploitation of the marl.

Commercially important formations.—Although most of the Cretaceous formations above the Raritan contain glauconite, only the Navesink, Hornerstown, and Manasquan marls are sufficiently glauconitic to be of commercial importance. These formations, together with the intervening Redbank, Tinton, and Vincentown sands and Shark River marl, are shown in detail on the accompanying maps (Pls. I–III, in pocket). The full development of the intervening sands in Monmouth County explains the great breadth of the marl belt in that county.

Southwest of Sykesville, in the northern part of Burlington County, the disappearance of the Redbank sand causes the Hornerstown and

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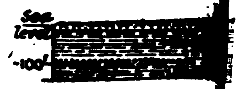

Vertical

Navesink marls to merge in a single formation in which both faunas may be recognized, but the respective parts of the formation are not clearly differentiated. Similarly the Manasquan marl practically disappears at a point about 4 miles southwest of Medford, in Burlington County. It has been recognized about 8 miles farther southwest in a small exposure near Clementon, in Camden County, and in Swedes Run, Salem County. Thus southwest of the vicinity of Marlton, in Burlington County, the marl belt practically includes only the combined bed of Navesink and Hornerstown and the Vincentown sand, which in that portion of the belt is locally very calcareous.

GEOLOGIC STRUCTURE.

The geologic structure of the New Jersey Coastal Plain, as shown in Plate V, is that of a series of gently inclined layers of poorly consolidated rock which have been beveled by erosion and many of which have been covered to a greater or less extent by later deposits. These layers of rock may be regarded as in large measure continuous throughout much of the Coastal Plain. Northwest of the area of its outcrop any particular bed is absent, but southeast of that area its depth increases regularly in the direction of the dip.

An idea more or less current in the marl region is that the marl along streams is of better quality than that in places between streams. Consideration of the structure as above outlined should show that a stream bears much the same relation to a marl bed as a carpenter's gouge or saw would to a board that was being shaped or cut. The tool might disclose differences in the grain or quality of the wood in the board but would have no part in producing those differences.

The analogy between the marl and the board is not complete, however, because ground water percolates through the marl at many localities and might be thought capable of removing fine particles, especially beneath stream beds, where underflow may be presumed to be relatively strong. Without a definite knowledge of the amount and distribution of the pore space of the marl in place it is impossible to deny that some removal of fine particles and consequent enrichment of remaining coarser material may be effected by ground water. On the other hand, the marl generally is compact, and the motion of ground water through it must be slow. The more clayey portions of the marl are in many places so tenacious that small dislodged masses of it successfully resist agitation in water for periods of several minutes. The differences noted in the marl are more probably to be ascribed, like the grain of the wood in the board, to original structure. If better marl has been found along streams than elsewhere the reason is probably because it is more abundantly exposed in stream valleys than elsewhere and

hence has been more commonly dug along the valleys. Further reference to enrichment is made on pages 133–135.

The gentle dip of the marl beds, previously noted, makes the area of their outcrop relatively broad and its outline intricate where crossed by streams. (See Pls. I–III, in pocket.)

NATURE OF THE EXPOSURES.

In fields and in roads the greensand gives a greenish color to the soil. In such places, however, the marl is likely to be mingled with other material. Locally it has proved to be redeposited marl, sand, and gravel of Quaternary age.

In the days when Cook wrote his general report on the geology of New Jersey, published in 1868, the marl business was flourishing, marl pits were open and shipping was in progress at many points all along the marl belt. With the introduction of prepared fertilizers and the decline of the marl industry most of the pits were abandoned and given over to water, swamps, and vegetation. The sides or banks have slumped and are now overgrown with brush and trees, some of which have trunks 3 to 6 inches in diameter, as in the large pit 2 miles northeast of Richwood, in Gloucester County (locality 44, Pl. I).

At a few pits, notably at Sewell and Birmingham, digging is in progress or has been recently. These pits give excellent exposures of portions of the beds but do not afford complete sections. Plate VI, *A*, shows some of the recent diggings and gives an idea of the present condition of one of the larger of the old pits. (See also Pl. IX, p. 80.) Exposures in road cuts give only partial sections and are seldom fresh. The same statement is true regarding stream valleys, except that the shell beds are locally well exposed in such places and thus furnish definite information about the position of the top or bottom of a bed. Plate VI, *B*, shows the shell bed at the base of the Navesink as exposed at Mullica Hill, in Gloucester County.

Quaternary beds overlie the greensand deposits in greater or less thickness almost everywhere and are locally difficult to distinguish from them. Tertiary beds are also present as part of the overburden in many places, as at Sewell. Complete sections of fresh material can be had only by boring. For this work doubtless the auger would suffice at many localities, but at others closely packed gravel and pebbles, loose wet greensand, heavy shell beds, or firmly cemented layers offer obstacles that only the drill can overcome.

FIELD WORK.

Selection of sites for drilling.—Preliminary trips, begun near Imlaystown, in the southwestern part of Monmouth County, and continued southwestward throughout much of the marl belt, soon

A. GENERAL VIEW OF WILLIAM HOFFMAN'S MARL PIT AT BIRMINGHAM, BURLINGTON COUNTY, N. J.

About three-fourths of a mile northwest of station. Shows recent digging at the north end and, in the distance, the old west bank of the pit.

B. SHELL BED AT THE BASE OF THE NAVESINK MARL AT MULLICA HILL, GLOUCESTER COUNTY, N. J., JUST EAST OF STATION.

demonstrated the need for drilling. Bids were invited, and the contract was let to Samuel J. Taylor, of Mount Holly.

In the selection of sites for drilling five requisites were considered. (1) The sites must be so spaced as to represent a considerable portion of the marl belt; (2) each site must be located in a tract large enough and flat enough for the establishment of a plant and the opening of pits; (3) the probable overburden should not exceed 10 to 15 feet; (4) the site must be along the southeast edge of the outcrop belt in order that the maximum thickness of the marl might be available; (5) the site must be near suitable means of transportation. On the basis of these requisities preliminary sites and alternates were selected by study of the map. These sites were then visited and the surrounding country inspected before final decision was made. The ownership of the land was then determined, and permission for drilling was obtained.

In such manner sites were selected at Salem and Woodstown, in Salem County; Sewell, in Gloucester County; Somerdale, in Camden County; Elmwood Road, in Burlington County; and other places which it was found impracticable to utilize. At each site a square containing 2½ acres was selected. Holes were sunk at each end of one side and a third hole for a check at the end or middle of the opposite side. At Salem and at Somerdale a fourth hole was sunk outside the square, but at Elmwood Road only two holes were sunk, the contract having expired before the third hole could be started. During the period November 20, 1918, to March 13, 1919, 16 holes were drilled under the contract. These were all in the combined Hornerstown and Navesink marls. In addition, through the courtesy of Mr. A. J. Mullen, superintendent of the Norcross & Edmunds Co.'s plant at Birmingham and Pemberton, men and tools were furnished for sinking three holes in the Manasquan marl on the property of that company. The distances between drilling sites range from 8 to 12½ miles.

The holes were sunk generally into or through the marl. They ranged in depth from 9 to 70 feet and averaged 37 feet. Of the 16 holes bored under contract 12 afforded complete sections from the surface through the marl beds. Observations were made on the character and thickness of the materials penetrated, and about 140 samples were collected for analysis. Numerous well records were also gathered.

After the drilling was completed a trip with the State geologist into parts of Monmouth County gave opportunity for brief inspection of additional portions of the marl belt.

Method of drilling.—Considerable variation was found in the character and behavior of the overburden and of the marl in regard t drilling at the different sites and in the different holes at the sam

site. Equipment and methods that worked well at one hole would be unsatisfactory at another. Thus at almost every hole a certain amount of experimentation was necessary to facilitate the work.

For two of the holes at Salem and for the first hole at Woodstown a light outfit, consisting of a 10-horsepower engine, winch, and tripod composed of 20-foot lengths of 1¼-inch pipe, was employed. Three-inch casing was used, and the drill bit and sand bucket were operated with ropes. Water filled the holes within a few feet of the surface. The marl had comparatively little binder, so that it could be removed only as sludge in the sand bucket. It was therefore necessary to follow the drill closely with the casing. For two of the holes at Salem a Cyclone drill of standard pattern was used. At Woodstown the tripod of the light outfit was replaced by a wooden derrick built into a portable rig, on which the engine and winch were also mounted (see Pl. VII, *A*), and this rig with modifications was used throughout the rest of the contract work.

In some of the holes where conditions were favorable the marl was removed directly with an auger. In some of the holes also a cylindrical tube was attached to the drill bar and driven down to obtain a core. This method proved on the whole unsatisfactory. There was more or less interchange from rope to rod tools and back again. The most rapid progress was made by the use of the drill bit and sand bucket attached to light rods and operated by hand by two men. On the Norcross & Edmunds property an 8-inch posthole auger with overlapping blades, one of which could be raised for removing the load, was used. This was operated by two men.

Method of sampling.—In sampling, as in drilling, the varying conditions at succeeding holes required more or less experimentation at each hole, and improvements in method came as experience with the material to be sampled grew. The aim was to procure fair average samples of all material from the top of the marl to the bottom and to have the samples represent uniform intervals, so far as was practicable. Uniformity of interval was prevented to a considerable degree by the conditions of the work. For example, where a 5-foot sample was intended a change of material might come within 1 foot and thus necessitate starting a new sample. Again, a change in the type of tool, as from auger to drill, or the close of work for the day before the desired depth had been reached would make advisable the beginning of a new sample.

At holes 6 and 7 at Woodstown, where a given bed seemed uniform, single augerfuls or bailings, taken at uniform intervals or after a noted change in the character of the marl, were considered representative samples. This method saved time but was discontinued in favor of the continuous-sample method.

A. DRILLING OUTFIT AND OPERATIONS AT WOODSTOWN, SALEM COUNTY, N. J

B. SAMPLING TROUGH IN USE AT ELMWOOD ROAD, BURLINGTON COUNTY, N. J.

So much water was present in most of the holes that the auger was generally ineffective at depths greater than 10 to 25 feet. The cylindrical bit with vertical slit for cleaning was effective in a few places, but where the material was incoherent it could not be brought to the surface. The more tenacious beds were penetrated only with difficulty by the cylinder, and the removal of material from it was very slow. The most expeditious method was drilling and sludging with the sand bucket, care being taken to case off beds that would be likely to modify the sample. Several samples taken by the auger or cylinder were taken in duplicate by the sludge method as a check.

Some experimentation was necessary in handling the material collected for samples. At hole 1, at Salem, the sludge was strained on cheesecloth spread over a perforated bucket or on screens on the ground. There was some loss of the claylike fines, but the lower layers of the sludge served as a filter for overlying layers, so that the loss of fines was thereby reduced. The remaining moist material, with a texture of somewhat clayey sand, was kneaded on oilcloth or canvas and divided six to eight times to duplicate samples weighing about 1½ pounds.

At hole 3, at Salem, the sludge was collected in barrels and allowed to settle over night, the water being then siphoned off. The remaining material was too wet to divide on canvas. It was therefore thoroughly mixed in the barrels and divided by discarding alternate bucketfuls until duplicates weighing about 1½ pounds were obtained. This method also involved some loss of fines because of the slow settling of the claylike portion and the difficulty of siphoning without stirring the light fines.

At Woodstown two especially constructed boxes, each fitted with a set of three screens, were employed. The solid material from the collecting barrel was spread on cheesecloth on the screens in the hope that it would filter the clayey water of the sample, which was then poured into the boxes. The operation was not successful. Either no water would pass through, or if it did the colloidal matter passed through with it. The collecting and filtering operations, both at Salem and at Woodstown, were seriously hampered by freezing. Filtering was abandoned, and the plan of dividing the solid and liquid portions separately and proportionally was tried, the end products of each division being combined for the final sample, which was then dried in pans over oil stoves, care being taken to avoid overheating and oxidation of the glauconite. It was feasible to collect some of the samples at Woodstown by means of the auger and the core tool. These samples were mixed and divided on canvas and dried on oil stoves.

At Sewell it was also possible to collect some of the samples without sludging, but that method proved necessary for many of them.

The labor of mixing and dividing large quantities of marl was obviated by using a trough with an end gate for collecting the sludge, as shown in Plate VII, *B*. The sludge in the trough was mixed thoroughly, and a sufficient quantity ladled out to provide duplicate samples, one of which was dried as above described and the other preserved in a 4-ounce wide-mouthed bottle. If more than one troughful was required for a given sample, proportionate amounts were preserved from each troughful and were mixed and divided for the final sample. This method was used at the other localities whenever sludging was necessary, care being taken to keep the sludge as thick as possible and to operate the sand bucket so as to take only material from the bottom of the hole.

Disadvantages of wet method.—The main disadvantage of the wet method of collecting marl samples is that by loosening the marl some of the finer constituents are mingled with water, and the relative proportions of coarse and fine materials are thereby slightly altered. The coarse constituents of the marl are relatively heavy and settle rapidly to the bottom of the trough, so that it is frequently difficult to get a uniform mixture. There is danger, too, of intermixture of material from farther up the hole, but this may be obviated to a considerable degree by suitable casing.

As shown on pages 125–126, the finer constituents of the marl contain potash in amounts varying from place to place and in different beds at the same place. Where the potash content of the fines of a given sample is less than that of the sample as a whole a loss of fines in collection would mean some enrichment of the sample, or an undue amount of fines collected would mean a corresponding impoverishment of the sample.

Three pairs of samples, one of each pair taken by the auger or core tool and the other by the wet method, at hole 8, at Sewell, show that the wet samples ran lower in total potash than the others by amounts ranging from 0.07 to 0.35 per cent, the average difference, weighted according to the thicknesses represented by the samples, being 0.285 per cent. As similar methods were followed at succeeding holes it seems probable that these figures show the order of discrepancy between the wet and auger or core-tool methods.

The lithologic character and potash content of the samples from Salem and Woodstown are comparable to similar features of samples from other holes, so that there appears to have been no undue enrichment or impoverishment of the samples from those localities on account of fines.

The potash was determined throughout this investigation by the method outlined by Hicks and Bailey.[3]

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[3] Hicks, W. B., and Bailey, R. K., Methods of analysis of greensand: U. S. Geol. Survey Bull. 660, pp. 51–58, 1918.

Determination of weight.—The density and moisture content as well as the potash content were determined for several samples of greensand, as shown in the accompanying table.

Potash, moisture, and density determinations for selected samples of New Jersey greensand.

[R. K. Bailey, analyst.]

Field No.	Locality.	K_2O.	H_2O at about 100° C.	Density.
		Per cent.	*Per cent.*	
M-7	Hole 3, Salem, (p. 23)	6.14	[a] 18.48	....
M-9	Hole 5, Woodstown (p. 31)	6.48	23.97	....
M-10	Hole 5, Woodstown (p. 31)	7.56	24.45	....
M-63	Sewell, West Jersey Marl & Transportation Co	7.80	20.50	2.958
K	Atlantic Potash Co., about 1¼ miles east of Marlton	7.63	14.20	2,925
R	R. S. Ryan plant at Reeves station, 2 miles north of Medford	6.25	17.38	3.063

[a] Sample damaged before reaching laboratory and contents transferred to bottle; hence H_2O content may be lower than that of actual sample.

Samples M–7, M–9, and M–10 were collected with the idea of finding how much water the greensand would retain when saturated. They were collected in an excess of water and forwarded to the laboratory in sealed cans. Before analysis they were placed in containers which would prevent evaporation but permit the excess water to drain away. The analyses show that marl taken directly from the pit and loaded without drying in wagons or freight cars, as was done by one company, may contain from 18.5 to nearly 25 per cent of water.

Sample M–63 was collected from a fresh stock pile gathered for shipment at a pit about three-quarters of a mile S. 70° E. from Sewell station and had been taken from the pit only a few moments before collection. It is a mixture of gray and dark-green marl.

Sample K was taken from a depth of 20 to 32 inches in the top of a stock pile that was probably less than a year old. It consisted of a mixture of green and brown marl judged in the field to be of excellent quality.

Sample R came from a freshly opened bed about 10 feet below the surface. It was black marl of apparently good quality.

Four determinations of the weight per cubic foot of greensand as taken from the ground were made in the field by weighing the material used to fill evenly a measured box of convenient size. A sample of the same material in each lot was preserved for the determination of moisture. The average weight of the material as taken from the ground according to these measurements was about 93 pounds to the cubic foot, or about 2,500 pounds to the cubic yard. The average weight of the dried material calculated from the moisture percentages in the above table was about 79.5 pounds to the cubic foot. A fifth determination of dried residues from several samples obtained at hole 6, Woodstown, gave 81.8 pounds to the cubic foot, but some of these residues had been exposed to the air for several days after

drying. The average weight of the five dried samples was about 80 pounds to the cubic foot, or 2,160 pounds to the cubic yard.

The figures given above are probably fairly accurate for the weight of the better material as ordinarily handled. Estimates of tonnage, however, are concerned with marl in the ground, which is presumably much more compact than marl removed to stock piles. According to the density determinations given in the table the weight of dry greensand, if massive and compact, would range from 182.7 to 191.4 pounds to the cubic foot and would average about 186 pounds to the cubic foot, or more than 5,000 pounds to the cubic yard. The marl in the ground, being unconsolidated, is probably much less compact than the degree required by this figure. Its actual weight doubtless lies between the two extremes given and for the purposes of estimate may be assumed to be their mean, 133 pounds to the cubic foot or about 3,580 pounds to the cubic yard. The voids, or open spaces due to lack of consolidation, would represent on this assumption 28 per cent of the mass of the marl.

Collection of well data.—During the progress of field work several well drillers were interviewed and farms on which wells had been sunk were visited. The well records at the office of the State geologist at Trenton were searched for data bearing on the districts explored. Published accounts were also reviewed with the hope of extending the inferences based on the drilling.

Other field data.—The field notes of the State geologist and his staff were kindly placed at the disposal of the writer and have been utilized to supplement the information gained by drilling.

GEOLOGIC MAP.

The geologic map as prepared by Knapp on the scale of 1 inch to the mile (1:63,360) has been adjusted to the somewhat larger base of the U. S. Geological Survey (1:62,500). (See Pls. I–III.) The map does not show Quaternary deposits, and as these are widely distributed throughout the area, it shows the actual surface conditions at comparatively few places. It is valuable, however, in showing the general breadth and outline of the areas in which the marl beds may be presumed to be within reach of the surface and may serve as a useful basis for tonnage estimates for any selected area. In its preparation Knapp visited all available exposures and made frequent tests with the auger. The map may be regarded as generally accurate. One or two slight modifications in it have been made as a result of the writer's observations. At a few other places surface examination suggested further modifications; but without opportunity for the detailed work necessary for revision it was thought best to leave the map unchanged. It is therefore presented essentially as drawn by Knapp but without delineation of the formations preceding the Navesink or succeeding the Shark River.

All localities discussed are referred so far as practicable to the maps (Pls. I–III), consecutive numbers being employed in order of reference. The locations of many of the wells are not accurately given in the available descriptions. The positions of such wells are indicated on the maps with a query (?).

RESULTS OF FIELD WORK.

SALEM DISTRICT.

SELECTION AND LOCATION OF SITES.

Published accounts give little information about greensand marl near Salem, but the geologic map of the State shows both the combined Hornerstown and Navesink marls and the Vincentown sand occupying broad areas near Salem and passing southwestward to Delaware River. Salem has railroad facilities and, through Salem Creek and its tributary Fenwick Creek, excellent means of water transportation. It was therefore decided to make Salem the starting point in the investigation.

The selected drilling sites lay on opposite sides of Walnut Street, about three-quarters of a mile S. 23° W. from the courthouse, on the farms of Louis Fogg and T. R. Miller. A supplementary hole was started in a field belonging to Lucius Hires, about a quarter of a mile north of the other sites.

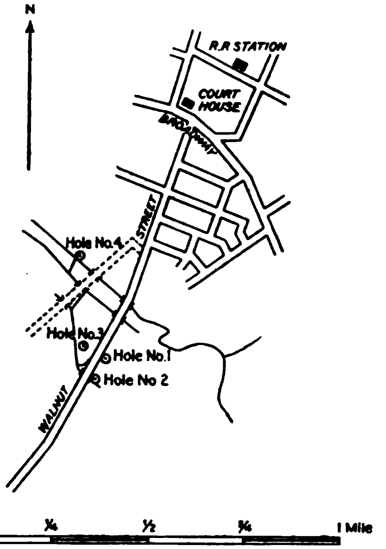

Figure 2.—Sketch map of part of the Salem district, showing the location of holes 1–4.

HOLES 1 TO 4.

The overburden at hole 1 proved so thick, 25 feet, that commercial development seemed unlikely. It was therefore determined merely to check the thickness and character of the overburden at the other holes in that vicinity and to confirm the character of the marl at one other locality. Thus at hole 2 only the overburden was penetrated; at hole 3, the overburden and 16 feet of marl, enough to show the presence of marl in commercial quantity and quality. At hole 4 the drill stuck in gravel at a depth of about 9 feet. Work was discontinued because of the thickness of the overburden in holes 1 to 3 and the reported thickness of overburden in wells in the vicinity. The positions of the four holes are shown in figure 2; their records follow.

Records of holes in Salem district.

Locality 1, hole 1.

[Farm of Louis Fogg, Walnut Street, Salem, about three-quarters of a mile S. 25° W. of courthouse. Elevation of surface, about 2 feet. S. J. Taylor, driller. Analysts: Chase Palmer (M-1 to M-4), R. K. Bailey (M-5.)]

	Thickness.	Depth.	Field No. of sample.	K_2O.	Formation.
	Ft. in.	*Ft. in.*		*Per cent.*	
Top soil and dark soil	1	1	....	....	Recent.
Clay, dark gray, sandy, with scattered quartz pebbles and including 6-inch water-bearing bed of yellow pebbly sand at depth of 3 feet 3 inches.	5 8	6 8	....	....	Pleistocene.
Gravel, coarse and fine angular fragments 1/16 inch to 2 inches in diameter, chiefly quartz, with some chert. More or less alternation of sand and gravel with considerable yellow clay, pebbles becoming more rounded. A few weathered needles of amphibole (?).	4 4	11	....	....	Do.
Sand, deep yellow to orange-yellow, with black specks; contains scattered tiny pebbles, especially near the top. Lowest foot glauconitic.	14	25	....	....	Do.
Clay, glauconitic, yellowish green, somewhat sandy, containing scattered pebbles ¼ to ½ inch in diameter and scattered chocolate-colored clay pellets.	1	26	M-1	6.11	
Glauconite beds, clayey, yellowish, with some coarse particles of quartz; grades into clay above. At base a few ferruginous and clayey nodules ¼ to ¾ inch in diameter and containing grains of glauconite.	4	30			Hornerstown.[a]
Glauconite beds with more or less grayish-yellow clay intermingled. Lowest foot nearly black; some nodules with grains of glauconite.	7 4	37 4	M-2	6.30	Do.
Glauconite beds, black, with grains of glauconite as large as 1/16 inch in diameter and a few grains of quartz.	4 3	41 7	M-3	6.57	
Glauconite beds containing considerable greenish clay, scattered tiny pebbles of quartz about ¼ inch in diameter, and glauconitic concretions as large as ½ inch in diameter.	1	42 7			Do.
Glauconite bed like last but toward base containing shell bed that was not measured but is probably only a few inches thick.	3 9	46 4	M-4	7.27	Do.
Glauconite beds with greenish clay in somewhat larger proportions than above. Some fragments of large shells (*Exogyra* or *Gryphaea*) and broken casts composed of consolidated greensand together with a few tiny pebbles ("rice gravel"?) are included.	2	48 4	M-5	7.26	Navesink (?)[a]
Sand, glauconitic and clayey; much quartz, some grains of which are fine enough to float by surface tension; clay, greenish gray, less abundant than in above beds; some shell fragments; water bearing.	4 2	52 6	....	....	Mount Laurel[a] and Wenonah.

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[a] For the use of these names in this and subsequent records see stratigraphic notes, pp. 135-137.

Locality 2, hole 2.

[Same general locality as hole 1, 310 feet S. 42° 3′ W. from it. Surface elevation, about 2 feet. C. C. Holladay, driller.]

	Thickness.	Depth.	Formation.
	Ft. in.	*Ft. in.*	
Soil and muck, dark colored	1	1	Recent.
Clay, gray, sandy	6 3	7 3	Pleistocene.
Gravel with yellow sand and small quartz pebbles, succeeded by lighter-colored sand and gravel containing pebbles; usually not over ½ inch but locally 2 inches in diameter; succession generally similar to that at hole 1.	8 9	16	Do.
Gravel, deeper yellow, less admixture of sand	8 8	24 8	Do.
Sand, yellowish to greenish, with increasing amount of glauconite.	9	25 5	Vincentown (?).
Glauconite beds with some admixture of yellowish clay, not penetrated.			

Locality 3, hole 3.

[Meadow belonging to T. R. Miller, on Walnut Street, about three-quarters of a mile south of courthouse at Salem and 330 feet N. 38° W. from hole 1. Surface elevation, about 2 feet. C. C. Holladay, driller. Analyst, R. K. Bailey.]

	Thickness.	Depth.	Field No. of sample.	K_2O.	Formation.
	Ft. in.	*Ft. in.*		*Per cent.*	
Top soil and black muck	2	2	....	....	Recent (?).
Clay, bluish gray, very smooth and soft, not gritty like that below soil in holes 1 and 2.	7	9	....	....	Do.
Clay, brown, peaty, with pieces of twigs and bark.	7	16	....	....	Do.
Gravel, grayish, containing small quartz pebbles and a pebble of greenstone 2 inches in diameter; becomes yellowish and finer textured with grains of glauconite in the lower part.	5	21	....	....	Pleistocene.
Glauconite beds, containing some yellowish clay.	5	26	M-7	6.14	Hornerstown.
Glauconite bed, at first coarse, then finer, with considerable clay.	5	31			
Glauconite beds with considerable green clay and scattered grains of quartz as large as ⅛ inch in diameter; lumps of green clay containing glauconite grains indicate more clayey layer at base.	5 6	36 6	M-8	7.72	Do.
Glauconite bed like those above; not penetrated.	6	37	....	....	Do.

Locality 4, hole 4.

[Meadow belonging to Lucius Hires, about 1,350 feet N. 10° W. from hole 1. Elevation of surface, about 2 feet. S. J. Taylor, driller.]

	Thickness.	Depth.	Formation.
	Ft. in.	*Ft. in.*	
Brown and black soil and muck	1 6	1 6	Recent.
Clay, gray, sandy	4 6	6	Pleistocene.
Sand, drab, very clayey, containing a few angular quartz pebbles and a gray sandstone pebble 2 inches in diameter.	6	6 6	Do.
Gravel with coarse pebbles, chiefly quartz, some as large as 2 inches in diameter; not penetrated further.	2 1	8 7	Do.

The data of holes 1 to 3 are summarized in the following table:

Thickness and quality of greensand beds at holes 1 to 3, Salem.

Hole.	Bed.	Sample.			Thickness of bed.	Average content of K_2O.[a]
		No.	Thickness represented.	K_2O.		
			Ft. in.	*Per cent.*	*Ft. in.*	*Per cent.*
1	Overburden	....	....	....	25	....
	Upper bed	M-1 M-2	5 7 4	6.11 6.30	12 4	6.22
	Middle bed	M-3 M-4	5 3 3 9	6.57 7.27	9	6.86
	Lower bed	M-5	2	7.26	2	7.26
2	Overburden	....	....	....	25 5	....
3	....do	....	....	....	21	....
	Upper bed	M-7	10	6.14	10	6.14
	Middle bed (not penetrated)	M-8	5 6	7.72	5 6	7.72
	Average:					
	Overburden	....	....	....	23 10	....
	Upper bed	....	....	....	11 2	[b]6.19
	Middle bed	....	....	....	[c]9±	[b]7.19
	Lower bed	....	....	....	2±	[c]7.26
					22 2	[d]6.69

[a] Average for bed weighted according to thickness represented by the respective samples.

[b] Average for bed in 2.5-acre tract weighted according to thickness at respective holes.

[c] Figures for hole 1 only.

[d] Average for entire thickness of marl in 2.5-acre tract, assuming that thicknesses for middle and lower beds at hole 1 apply to entire area.

WELL DATA.

According to Twitchell[4] six wells have been drilled at Salem for J. Q. Davis, east of the railroad station, on the margin of the meadow adjoining Fenwick Creek, at an elevation of 3 to 5 feet. Three of these wells are 130 feet deep and three 100 feet. The water rises within 1 or 2 feet of the surface. As is shown by the record below, the wells start in the Vincentown sand, which, with a foot of overlying marsh mud, constitutes an overburden of 20 feet. The combined Hornerstown and Navesink marls are 35 feet thick, and the water is taken from the underlying Mount Laurel and Wenonah sands.

Record of well of J. Q. Davis, at locality 5, Salem.

[Elevation, 3 feet; depth, 130 feet.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Marsh mud, roots, etc	1	1	
Yellow sand with some greensand	19	20	Vincentown.
Olive-green marl	10	30	Hornerstown and Navesink.
Dark-green marl	10	40	Do.
Green marl, slightly lighter in color	15	55	Do.
Sand with *Belemnites* and some fragments of shell	5	60	Mount Laurel and Wenonah.
Sand, water bearing	70	130	Do.

If Twitchell's interpretation of the record at locality 5 is correct the boundary between the Vincentown and Hornerstown should be drawn far enough west to include at least this locality.

A well at Oakdale farm (locality 6), about a quarter of a mile southeast and down the dip of the beds from locality 5, shows 40 feet of marl beneath an overburden of 30 feet of clay, gravel, and sand.

Record of well of Stewart Craven at locality 6, Salem.

[About 0.4 mile S. 52° E. from railroad station, on south side of street. Elevation, about 10 feet. C. C. Holladay, driller and informant.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Clay, gravel, sand	30	30	Pleistocene and Vincentown (?).
Blue and black marl	40	70	Hornerstown and Navesink.
Sand with some marl mixed in it (marl may have come from above).	10	80	Mount Laurel and Wenonah.
Sand with good water	23	103	Do.

It seems likely that much of the overburden here is Pleistocene rather than Vincentown. The same statement is probably true regarding localities 1 to 4, as shown by the detailed records. At locality 5 also Pleistocene beds may form a larger share of the overburden than is thought by Twitchell.

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[4] Twitchell, M. W., unpublished manuscript.

The northwestward beveling of the greensand marl by erosion is perhaps shown by the following record:

Record of well of H. J. Heinz Co. at locality 7, Salem.

[Fenwick Creek, about 0.35 mile N. 42° W. of railroad station. Elevation, about 3 feet. C. C. Hulladay, driller and informant.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Clay	8	8	Pleistocene.
Green marl	3	11	Hornerstown and Navesink (?).
Black sand or blue marl	6	17	Do.
Yellow sand	53	70	Do.
Gravel and gray sand	5	75	

If the green and blue marl of the above record are undisturbed a diminution of 26 to 31 feet in the thickness of the marl has occurred between localities 6 and 7. The overburden also has been reduced from 20 or 30 feet to only 8 feet. The thick yellow sand and the gravel in the lower part of the hole suggest that the entire mass of the material penetrated by the well may be Pleistocene and may represent filling in the formerly more deeply eroded valley of Fenwick Creek. Present data are insufficient to determine this point.

A 40-foot well drilled by Haines Bros. for Howard Harris [5] about 1 mile west of Salem penetrated only fine yellow sands to a point near the bottom, where the color changed to white. These sands are probably Pleistocene. This well is cited merely to show the thickness of Pleistocene overburden that may be expected along the lower course of Salem Creek and in low-lying lands near the Delaware.

A well at Moores Corner, about 1.2 miles south of the courthouse at Salem, shows the continuance of thick beds of marl along the strike, but it shows also the increase in overburden toward the southeast. The record follows:

Record of well of Frank Brown at locality 8, Moores Corner.

[Opposite fork and about 100 feet east of road. Elevation, about 11 feet; depth, 120 feet. C. C. Holladay, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Coarse gravel	4	4	Pleistocene.
Sand	3-4	8	Do.
Yellow clay	32±	40	Do.
Greensand	25-30	70	Hornertown and Navesink.
Black sand, water bearing	50	120	Mount Laurel and Wenonah ?

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[5] New Jersey Geol. Survey Ann. Rept. for 1901, p. 105, 1902.

Southeast of the area mapped as Vincentown three additional borings throw light on the thickness and character of the overburden in that district.

A well drilled for Dr. Hummel at Sandy Ridge farm (locality 9), about 1 mile N. 42° W. of the Quinton railroad station, shows, according to C. C. Holladay, driller, 36 feet of overburden and 23 feet of "light-colored marl." This marl may be Vincentown, but it lies within the area mapped by the State Geological Survey as Kirkwood and may represent a marly phase of that formation, which farther southeast is known as the Shiloh marl member of the Kirkwood formation, and was formerly dug as a fertilizer.[6]

A well near Hagerville gives the following record:

Record of well of James Pettit at locality 10, about half a mile southeast of Hagerville.

[South side of road. Elevation, 5± feet. C. C. Holladay, driller and informant.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Clay, gravel, and sand	17	17	Pleistocene.
Shell marl; effervesces strongly with acid	10	27	Kirkwood (?).
Quicksand	58	85	Do.
Sand and coral; stopped in coral	15	100	Vincentown (?).

It is supposed that the upper bed of marl in this well may represent the Shiloh marl member and the lower bed the lime sand or Vincentown. Upon this assumption the Hornerstown marl at locality 10 will lie 110 feet or more beneath the surface.

The well of Jerry Powell, on the west bank of Hope Creek near its mouth (locality 11), "a stone's throw from the Delaware," is said by C. C. Holladay, driller, to be 264 feet deep. The greensand is 40 feet thick and 200 feet below the surface. Water is obtained from a yellow sand beneath the marl. The marl is very compact.

Two wells about 2¼ miles east of Alloway on the road to Daretown show the increase in depth of the marl beds in the direction of the dip. One well is on the farm of Parvin Lloyd and the other on the farm owned by Samuel C. Reeve and occupied by Henry Hile. Both wells are at an elevation of about 40 feet. Woolman[7] presents the following combined record:

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[6] Cook, G. H., Geology of New Jersey, pp. 471-473, 1868.

[7] Woolman, Lewis, Artesian wells: New Jersey Geol. Survey. Ann. Rept. for 1901, p. 102, 1902.

Combined record of two wells 2½ miles east of Alloway.

[No. 1: Elevation, 40 feet; depth, 240 feet; driller, Abraham Darlington. No. 2: Elevation, 30 feet; depth, 205 feet; drillers, Haines Bros.]

	Thickness.	Depth.	Age or formation.
	Feet.	*Feet.*	
Yellow clay	18	18	Miocene in part at least.
"Blue mud"	90	108	
"Marl and sand"	72	180	Mostly lime sands [Vincentown].
Gray rock	7½	181½	Do.
Sand, water-bearing	8½	190	Do.
Gray rock (9 inches)	1	191	Do.
"Marl and sand," well No. 2	14	205	Middle marl.
Do	35	240	[Hornerstown and Navesink].

The thickness of the lime sand here is noteworthy, as is also the thickness of the marl, which lies 191 feet below the surface.

Record of well of Salem Water Co. at Quinton.[a]

[Depth, 248 feet; Kisner & Bennett, drillers.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Surface soil	1	1	Recent.
Gravel	3	4	Do.
Clay with shells	26	30	[Kirkwood.]
Green and white sandy, clayey marl	8	38	[Manasquan.]
Alternations of lime sand and limerock.	108	146	[Vincentown.]
Clay	2	148	[Hornerstown and Navesink.]
Greensand marl and shell comminuted by drill	14	162	Do.
Clay	4	166	[Mount Laurel and Wenonah.]
Gray quartzose sand with water	82	248	Do.

[a] New Jersey Geol. Survey Ann. Rept. for 1894, p. 194, 1895.

In the above record the formation names in brackets are substituted by the writer for those used in the report cited. The thickness of the lime sand (108 feet) is remarkable. The thickness of the combined Hornerstown and Navesink is rather low.

OTHER DATA.

The exposures of the three important marl beds nearest to Salem occur along Mannington Creek and its tributary Swedes Run in Mannington Township, from 3 to 5 miles northeast to nearly east of Salem. The limestone phase of the Vincentown sand is also exposed at the same locality. These formations were dug and utilized as fertilizer years ago, and analyses of samples from them are given by Cook.[a]

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[a] Cook, G. H., Geology of New Jersey, pp. 441-442, 1868.

LIME SAND.

The use of lime in extracting potash from greensand lends interest to the occurrences of the lime-sand and limestone phases of the Vincentown sand as possible sources of the lime. The following analyses given by Cook show the character of this material:

Analyses of limestone and lime sand from the Vincentown sand in Mannington Township.[a]

	1	2	3		1	2	3
Phosphoric acid	0.04	0.20	....	Alumina	0.91	0.86	6.20
Sulphuric acid	.06	.23	....	Oxide of iron	3.07	3.56	
Silicic acid	23.31	8.11	43.40	Carbonate of lime	69.61	84.73	44.45
Magnesia	1.81	1.40	1.95	Water	.24	.45	....
					99.05	99.54	96.00

[a] Cook, G. H., op. cit., pp. 441–442.

No. 1 is described as a fair sample of the "Yellow limestone" in Mannington Township. No. 2 is described as lime sand from pits of John Fowler, Swedes Bridge, Mannington Township. This is a sample of the loose variety, is gray in color, and contains many greensand grains. No. 3 is described as lime sand from William Barber's pits, along a branch of Mannington Creek, Mannington Township. This lime sand was extensively used as a fertilizer. The stony layers were burned for lime, which had a wide use and gave good satisfaction.

These pits have long been idle and have probably passed into other ownership, but the general locality can readily be identified from the map. The average content of carbonate of lime for the three samples is 66.3 per cent. The low magnesia content is noteworthy. Measurements of thickness are not now available, but the former use of the lime sand suggests its presence in commercial quantity. Cook[9] writes: "William Barber's yellow limestone quarry is perhaps the finest in the State; he has dug 25 feet in it without finding bottom; it is made up of alternating tabular masses of limestone and lime sand, the stone from 4 to 12 inches thick and the sand from 8 inches to 2 feet thick."

The Shiloh marl, to which reference has already been made, was dug on branches of Stow Creek along the county line, about 9 miles southeast of Salem. The five analyses given by Cook[10] show a maximum content of about 15 per cent of carbonic acid (CO_2), equivalent to 32 per cent of carbonate of lime. These analyses show a maximum of 2 per cent of phosphoric acid and of 1.55 per cent of potash and soda combined.

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[9] Cook, G. H., op. cit., p. 273.

[10] Idem, pp. 471–472.

ESTIMATES OF TONNAGE AND VALUE.

At locality 1 the thickness of the marl sampled was 23.3 feet. At locality 3 the thickness sampled was 15.5 feet, but the marl at this locality was not penetrated. The average of the thicknesses sampled is 19.4 feet, but for purposes of computation it may safely be assumed as 20 feet. The average potash content, weighted according to the thicknesses represented by the respective samples, is 6.62 per cent. The weight per cubic foot of marl, on the assumption of 28 per cent of voids, as explained in a previous paragraph, is 133 pounds. On this basis 1 acre would contain $\frac{43,560 \times 20 \times 133 \times 0.0662}{2,000} = 3,800$ tons of potash (approximately), and 2.5 acres would contain 9,500 tons.

With an 80 per cent recovery and a price of $2.50 per unit (March, 1920), the available potash in a ton of greensand from the localities sampled (6.62 per cent K_2O) would be worth $13.24 and that in an acre $760,000. It is doubtful, however, if the price of potash can be maintained at that figure. At $1.50 per unit under the same conditions the available potash in a ton of greensand would be worth $7.94, and that in an acre $456,000. These values have only theoretical interest, as they depend upon the potash being made available by processes whose success has not been demonstrated.

Although the estimates given are for a single area of 2.5 acres the well records cited show that greensand marl occurs generally beneath the Salem area. The wells at localities 5, 6, and 8 show thicknesses of greensand ranging from 25 to 40 feet. These wells, as also the borings at localities 1 and 3, are near the southeastern border of the beveled greensand belt, where the thickness is greater. Toward the northwest the thickness may be presumed to diminish to zero along the general northwestern border of the belt.

UTILIZATION OF THE DEPOSITS.

The record of the well at locality 7 appears to show that the overburden may not be as thick along Fenwick Creek as elsewhere in the Salem district. On the other hand, the marl shown in that record may be reworked material of Pleistocene age and if so may have a lower percentage of potash than the undisturbed Cretaceous deposits. Systematic prospecting along the creek would be necessary to settle these uncertainties.

Elsewhere the overburden in the Salem district appears to be too thick to permit any immediate utilization of the greensand in the Hornerstown and Navesink marls, but the deposit may be regarded as a resource of possible future value.

WOODSTOWN DISTRICT.

SELECTION AND LOCATION OF SITES.

Considerable marl reported as of good quality was dug in the vicinity of Woodstown in the early days, and the material is still readily accessible, as is also the lime sand, which occurs in several stream valleys near the town. Railroad transportation is available, and Salem Creek has been reported as navigable below Sharptown. It is now utilized as far up as Course's Landing. Woodstown thus seems a favorable place for commercial development of the marl.

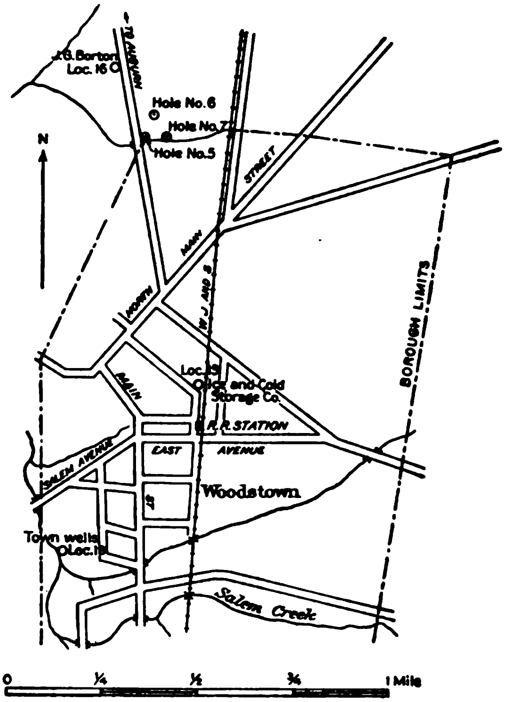

FIGURE 3.—Sketch map of part of the Woodstown district, showing the locations of holes 5 to 7 and of certain wells near Woodstown.

The site selected is a field belonging to Isaac K. Lippincott, at the north boundary of the borough, east of the road between Woodstown and Auburn, as shown in figure 3.

HOLES 5 TO 7.

Three holes were sunk in an area of 2½ acres; their records follow:

Records of holes in Woodstown district.

Locality 12, hole 5.

[Field of Isaac K. Lippincott, about 1 mile north of Woodstown station, 20 feet east of culvert on road to Auburn, on north side of creek. Elevation of surface about 48 feet. S. J. Taylor, driller; R. K. Bailey, analyst.]

	Thickness.	Depth.	Field No. of sample.	K_2O.	Formation.
	Ft. in.	*Ft. in.*		*Per cent.*	
Soil, grayish to brownish, clayey, with some sand and grass roots; scattered quartz pebbles as large as 1 inch in diameter.	6	6	....	....	Recent.
Clay, sandy, with pebbles larger and more numerous than above; some lumps of greensand.	1	1 6	....	....	Pleistocene.
Sand, yellow, with larger proportions of greensand and some pebbles.	2 9	4 3	....	....	Do.
Sand, yellow, becoming greenish with increasing proportion of glauconite, few if any pebbles; grades downward into glauconite beds.	1 9	6	....	....	Do.
Glauconite beds with considerable greenish-gray clay and fine quartz particles. Some scattered pebbles more than ½ inch in diameter, and some gravelly material possibly worked down by sticking of pipe.	1 11	7 11	....	....	
Glauconite beds containing some fine sand......	1 1	9	M-9	6.48	Hornerstown.
Glauconite beds, dark greenish gray, compact, clayey, plastic.	11 8	20 8			
Glauconite beds, somewhat coarser; include a few grains of quartz and chert about $\frac{1}{16}$ inch in diameter and a few pieces of shell. At 22 feet material becomes runny. Two small pebbles noted.	5 5	26 1	M-10	7.56	Do.
Glauconite beds with considerable light-green clay, more firm. Lowest 1 foot contains fragments of shell and some quartz grains.	3 2	29 3			
Glauconite beds, with much drab-gray clay, little or no quartz. At 32 feet material becomes soft and tends to run. At 33 feet 8 inches chocolate-colored clay pellets appear in glauconite material, also scattered coarse grains of quartz.	10 4	39 7	M-11	7.14	Navesink.
Glauconite beds with much gravel, considerable drab clay and some shell fragments; water-bearing.	2 2	41 9	....	....	Mount Laurel and Wenonah.

Locality 13, hole 6.

[Field of Isaac K. Lippincott, Woodstown, 375 feet N. 30° E. from hole 5. Elevation of surface about feet. S. J. Taylor, driller; R. K. Bailey, analyst.]

	Thickness.	Depth.	Field No. of sample.	K₂O.	Formation.
	Ft. in.	*Ft. in.*		*Per cent.*	
Top soil, dark, clayey, with some sand..........	1	1	....	....	Recent.
Clay, sandy, grayish..............................	4	1 4	....	....	Pleistocene.
Gravel, yellow, in matrix of sand and clay; quartz pebbles as large as 2½ inches in diameter.	8 8	10	....	....	Do.
Glauconite beds, stiff, with dark-greenish to black clay, containing some small rounded quartz pebbles ¼ inch in diameter. One smooth ovate pebble noted at bottom.	3 1	13 1	M-12	5.74	Hornerstown.
Glauconite beds, clayey, homogeneous, with somewhat larger proportion of black glauconite.	5 3	18 4			
Glauconite beds similar to above but including at base a few inches of underlying stratum.	2 2	20 6	M-13	5.79	Do.
Glauconite beds with greenish-drab clay, much intermingled quartz sand, and yellow grains probably of weathered ferruginous chert; coarser grains of clear and yellow-stained quartz and chert as large as ½ inch in diameter, angular and rounded; runs into pipe, water bearing; not sampled.	1 4	21 10	....	....	Do.
Glauconite beds, black, clayey, viscous, apparently uniform. (Sample M-14=2 feet of material from 21 feet 10 inches to 23 feet 10 inches.)	3 2	25	M-14	6.98	Do.
Glauconite beds, green, larger proportion of glauconite; runs easily; uniform character; sample bailing taken at depth of 29 feet. One fish tooth observed.	5	30	M-15	7.88	Do.
Glauconite beds, green, greater proportion clay, stiff, fine textured, apparently uniform. Sample M-16 represents material from depth of 30 to 31 feet.	4 7	34 7	M-16	7.80	Do.
Glauconite beds, less clayey, green material with larger proportion of glauconite, fine texture, soft; tends to run. Sample M-17 taken from a bailing at depth of 34 feet 7 inches but apparently representative of entire thickness.	5 5	40	M-17	7.76	Do.
Glauconite beds, brownish black, comparatively little clay. Sample M-18 taken from a bailing at depth of 40 feet but considered representative of entire thickness.	3 6	43 6	M-18	7.56	Navesink.
Glauconite beds, brownish black, containing gravel, sand, clay, and much glauconite. Gravel grains 1/16 to ¼ inch in diameter; some of clear quartz, angular; others rounded and composed of quartz and chert. Chocolate-colored clay pellets ¼ to ½ inch in diameter also present. Some of gravel grains smooth and polished ("rice gravel").	1 6	45	M-19	2.92	Do.
Glauconite beds containing progressively more quartz sand but less clay and glauconite.	2 7	47 7	....	....	Mount Laurel a Wenonah.

Locality 14, hole 7.

[Field of Isaac K. Lippincott, Woodstown, 330 feet S. 83° E. from hole 5. Elevation of surface about 50 feet. S. J. Taylor, driller; R. K. Bailey, analyst.]

	Thickness.	Depth.	Field No. of sample.	K_2O.	Formation.
	Ft. in.	*Ft. in.*		*Per cent.*	
Soil, brown, clayey	1	1			Recent.
Clay, brown, stiff, becoming gray and sandy toward base.	1 6	2 6			Pleistocene.
Gravel, matrix of grayish-drab clayey sand, quartz pebbles as large as 1½ inches in diameter.	8	3 2			Do.
Clay, very sandy, deep yellowish brown, with some streaks of gray sandy clay.	10	4			Do.
Clay, brown, sandy, with a few pebbles and some grains of glauconite that give a greenish tint.	1	5			Do.
Gravel with quartz pebbles as large as 1½ inches in diameter. Matrix sandy clay, compact.	1	6			Do.
Sand, glauconitic, with some clay and a few small pebbles, greenish brown, becoming more greenish downward with increasing proportion of glauconite. At depth of 11 feet washed sample contained a large percentage of quartz sand and some grains of gravel, which may have descended from above in drilling.	6 6	12 6			Vincentown (?)
Glauconite beds, grayish green, stiff clayey material, becoming somewhat more compact at base. Sample M-20, taken from 12 feet 6 inches to 13 feet 6 inches, regarded as representative of bed.	4 8	17 2	M-20	5.66	Hornerstown.
Glauconite beds, grayish green, soft; tends to run. Sample M-21 taken from a bailing at depth of 18 feet, regarded as representative.	1	18 2	M-21	5.62	Do.
Glauconite beds, more greenish color, upper 18 inches fairly stiff; lower part soft, with tendency to run. Less clay and quartz than overlying bed. Numerous shell fragments, nodules of marcasite with included grains of glauconite. Sample M-22 represents 1 foot of material taken at depth of 20 to 21 feet but regarded as typical of entire bed.	5 10	24	M-22	6.48	Do.
Glauconite beds of lighter-green color due to admixture of green clay; glauconite grains fine and black, soft, with tendency to run. Nodules of marcasite and a few clay pellets present. Sample M-23 regarded as representative of bed, but includes only material from 25 to 26 feet.	2	26	M-23	7.37	Do.
Glauconite beds, grayish black, containing pieces of shell and a few quartz pebbles ranging from ½ to 1½ inches in diameter. At 27 feet sample M-24 taken of water circulating through glauconite beds. Sample M-25 taken from bailing at depth of 31 feet regarded as representative of entire bed.	5 6	31 6	M-24[a] M-25	[b]5.37 7.40	Do.
Hardpan, dense rock composed largely of iron carbonate and containing scattered grains of glauconite; whitish when first encountered but purplish drab after drying and standing.	6	32			Do.
Glauconite beds, thin; green clayey layer, then greenish to blackish-gray material, rather soft, in alternating layers. Sample M-26 from a bailing at depth of 34 feet regarded as representative of bed below the hardpan.	5	37	M-26	6.66	Navesink.
Glauconite beds; stiff clayey layer about 3 inches thick succeeded by water-bearing glauconite and quartz sand 6 inches thick.	9	37 9	M-27	4.74	Do.
Glauconite beds, blackish-gray material, rather soft and uniform.	2 9	40 6			Do.
Glauconite beds with some gravel, water bearing.	6	41			Do.
Glauconite beds, somewhat coarser. Sample taken from bailing at 41 feet.	2	43	M-28	6.57	Do.
Glauconite beds, containing casts of gastropods, pieces of shell, rice gravel, and considerable clay. Grades downward into more sandy material with continuation of rice gravel.	6	49			Mount Laurel and Wenonah.
Sand, mostly quartz but with some glauconite, clay, and shell fragments.	1	50			Do.

[a] Water only.

[b] Dried residue from water sample.

The data of holes 5 to 7 are summarized in the following table:

Thickness and quality of greensand beds at holes 5 to 7, Woodstown.

Hole.	Bed.	Sample. No.	Sample. Thickness represented.	Sample. K_2O.	Thickness of bed.	Average content of K_2O.[a]
			Ft. in.	*Per cent.*	*Ft. in.*	*Per cent.*
5	Overburden				7 11	
	Gray marl	M-9	12 9	6.48	12 9	6.48
	Green marl	M-10	8 7	7.56	8 7	7.56
	Chocolate marl	M-11	10 4	7.14	10 4	7.14
6	Overburden				10	
	Gray marl	M-12	8 4	5.74	11 10	[b]5.75
		M-13	2 2	5.79		
			1 4			
	Green marl	M-14	3 2	6.98	18 2	7.67
		M-15	5	7.88		
		M-16	4 7	7.80		
		M-17	5 5	7.76		
	Chocolate marl	M-18	3 6	7.56	5	6.17
		M-19	1 6	2.92		
7	Overburden				12 6	
	Gray marl	M-20	4 8	5.66	11 6	6.07
		M-21	1	5.62		
		M-22	5 10	6.48		
	Green marl	M-23	2	7.37	8	[c]7.39
		M-25	5 6	7.40		
			6			
	Chocolate marl	M-26	5	6.66	11	[d]6.45
		M-27	9	4.74		
			3 3			
		M-28	2	6.57		
	Average: Overburden				10 2	
	Gray marl				12	[e]6.12
	Green marl				11 7	[e]7.58
	Chocolate marl				8 9	[e]6.69
					32 4	[f]6.80

[a] Average for bed weighted according to the thicknesses represented by the respective samples.
[b] Average for 10 feet 6 inches.
[c] Average for 7 feet 6 inches.
[d] Average for 7 feet 9 inches.
[e] Average for bed in 2.5-acre tract weighted according to thickness at the respective holes.
[f] Average for entire thickness of marl in the 2.5-acre tract.

WELL DATA.

A number of wells drilled in the vicinity of Woodstown furnish supplementary data regarding the thickness of the overburden and of the marl. Three of these wells (at localities 15 to 17) were sunk during the field investigation by the Survey party.

Record of well of Joseph Allen at locality 15, near Woodstown.

[Well is 1.1 miles S. 84° W. of railroad station, on north side of road. Elevation, about 50 feet; diameter, 6 inches; depth, 105 feet. Joseph Allen, informant; C. C. Holladay, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Overburden largely yellowish-gray clay with some gravel; white quartz pebbles as much as 1 inch in diameter on dump.	13	13	Pleistocene.
Marl	58	71	Vincentown (?) to Navesink.
Sand; bottom of well in white sand	34	105	Mount Laurel and Wenonah.

Although the shell bed at the top of the Hornerstown is not present in this well it occurs in openings on Mr. Allen's property about 3,500 feet to the southwest. The thickness of the marl seems a little excessive, but the bed was reported as all greensand. Probably some of the glauconitic phase of the Vincentown is included.

A well drilled earlier probably not far from locality 15 shows a somewhat different record.

Record of well of Charles E. Allen, about 1 mile west of Woodstown.[a]

[On road to Sharptown. Elevation, about 50 feet; depth, 135 feet. Haines Bros., contractors.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Surface deposits, clay, gravel, etc	30	30	Pleistocene.
Light-colored sand	5	35	Kirkwood.
Black mud	15	50	Do.
Lime sand mixed with marl	15	65	Vincentown.
Greensand marl	35	100	Hornerstown and Navesink.
Sand and marl mixed	15	115	Mount Laurel and Wenonah.
Gray sand with water	20	135	Do.

[a] New Jersey Geol. Survey Ann. Rept. for 1901, p. 101, 1902.

Record of well of J. Gilbert Borton at locality 16, near Woodstown.

[About 0.21 mile beyond the borough limits of Woodstown, on west side of road to Auburn. Elevation, about 55 feet; diameter, 4½ inches; depth, 75 feet. Chalkley Haines, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Soil	1	1	Recent.
Clay	11	12	Pleistocene.
Yellow sand and gravel	3	15	Do.
Marl with greenish clay, blacker near bottom	30	45	Hornerstown and Navesink.
Gray sand fairly uniform	30	75	Mount Laurel and Wenonah.

Record of well of William Cole at locality 17, near Woodstown.

[About 0.83 mile north of borough limits of Woodstown, on west side of road to Auburn. Elevation, about 68 feet; depth, 30 feet. Chalkley Haines, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Dug well	20	20	Pleistocene (?) and Cretaceous.
Marl	10	30	Hornerstown and Navesink.
Gray sand			Mount Laurel and Wenonah.

The overburden at locality 17 is probably slight, and most of the well is in greensand marl.

The following notes on the deep wells supplying water to the borough of Woodstown, which were kindly furnished by Dr. Twitchell,[11]

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[11] Twitchell, M. W., unpublished manuscript.

of the State Survey, will be of interest to any company that proposes commercial development of the greensands:

> The town supply of Woodstown, Salem County, is drawn in part from six wells near the bank of the creek at an elevation of about 20 feet and varying from 136 to 149 feet in depth. The average flow of each well from the top of the casing, 1 foot above the surface, is about 60 gallons per minute; temperature 58°. The wells draw from the Mount Laurel-Wenonah sands, which were water-bearing from 60 to 114 feet below sea level. A seventh well at this point was prospected to 776 feet. Water-bearing sands were found at the top of the Magothy-Raritan formation from 276 to 319 feet below sea level and also near the bottom of the series at 756 feet below sea level. Between these two horizons an alternating series of sands and white and red clays was found, all of which apparently belong to the Raritan and Magothy formations, which here have a thickness of 480 feet, with base not reached. The water at 296 feet (276 feet below sea level) rose within 14 feet of the surface, and that from 776 feet (756 feet below sea level) within 18 feet. In 1915 a new well was driven to a depth of 340 feet, which drew upon the upper horizon in the Magothy-Raritan at 310 feet. The yield of this deep well on pumping is 300 gallons per minute, and it has therefore proved an important addition to the town supply.

Available records of the 340-foot well differ somewhat, but the following, taken from a letter in the files of the State Geological Survey, checks fairly well with the samples now preserved at the pumping station and kindly shown to the writer by Mr. Oren Conover, city engineer.

Record of well of Borough of Woodstown at locality 18.

[Elevation, about 20 feet; depth, 340 feet. Haines & Hollinshead, drillers.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Meadow mud and gravel	15	15	Quaternary.
Limestone	10	25	Vincentown.
Green marl	40	65	Hornerstown and Navesink.
Chocolate marl, hard	10	75	Do.
Gray sand, water bearing	75	150	Mount Laurel and Wenonah.
Black clay marl	160	310	Marshalltown to Merchantville ?
White sand and gravel	30	340	Magothy ?

The samples of material below the marl show some variation from the description in the above record. Samples taken at depths of 185 and 210 feet show a fine-textured micaceous gray clayey sand, containing small pebbles and fragments of shell. These represent the Englishtown sand, which was not utilized. The entire thickness of greensand marl is present, for both shell beds appear to have been penetrated, as indicated by the samples.

Three wells have been drilled for the Ice & Cold Storage Co., one block north of the depot, at an elevation of 50 feet (locality 19). The writer is indebted to Dr. Twitchell for the following description:

> Two of the wells have a diameter of 6 inches, the other of 4½ inches; the last and one of the 6-inch wells are 160 feet deep and obtain water from the Mount Laurel-Wenonah sands 50 to 110 feet below sea level—the same horizon which supplies the

shallower town wells. This water rises within 16 feet of the surface. The other well has a depth of 360 feet and draws from a water-bearing sand at the top of the Magothy 270 to 310 feet below sea level; the water rises within about 50 feet of the surface. The Englishtown sand was found at a depth of 190 to 210 feet (140 to 160 feet below sea level) and was slightly water-bearing.

It is evident, therefore, that at Woodstown four water horizons have been recognized, two of which are utilized—in the Mount Laurel-Wenonah sand at 50 or 60 feet below sea level, in the Englishtown sand at 140 feet below sea level, at the top of the Magothy-Raritan beds at 270 to 276 feet below sea level, and in the Raritan beds at 756 feet below sea level.

Although the Vincentown occurs here and is covered by a layer of Kirkwood clay, it is not reported as water-bearing.

The following is the detailed section for the deepest well near the depot. Notes on the fossils found in this boring were published in the annual report for 1901, page 93. The statement that *Belemnitella* was found at 240 to 250 feet in the Woodbury is regarded as of doubtful accuracy, as this form has never been reported from any of the outcrops of the Woodbury.

Record of well of Woodstown Ice & Cold Storage Co. at locality 19.

[Elevation, 50 feet; diameter, 6 inches; depth, 360 feet. Haines Bros., contractors.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Gravel and yellow clay	25	25	Pleistocene.
Black clay	5	30	Kirkwood.
Lime sand with Foraminifera	10	40	Vincentown.
Shell layer containing *Gryphaea*, *Terebratula*, and other fossils.	10	50	Hornerstown and Navesink.
Pure greensand marl, very dark	30	80	Do.
Lighter-green greensand marl, mixed with light-gray clay; contains *Belemnites* at about 90 feet.	10	90	Do.
Slightly clayey, dull yellowish-gray sand, about one-third greensand, two-thirds whitish quartz sand, with *Belemnites* and molluscan fossils.	45	135	Mount Laurel and Wenonah.
Black and white clear sand; resembles pepper and salt mixture; *Belemnitella*, *Terebratula*, and other fossils, etc.	25	160	Do.
(The last two divisions, from 100 to 160 feet, are largely water bearing throughout and supply wells Nos. 1 and 2.)			
Clayey greensand with molluscan fossils	10	170	Marshalltown.
Dark sandy clay; large admixture of white quartz sand with a smaller proportion of greensand; contains mollusks, Foraminifera, and other fossils, same as Marshalltown.	20	190	Do.
Greenish-gray sand, consisting of white quartz and greensand grains, the former predominating. This stratum was slightly water bearing but was not utilized. These specimens contained mollusks, Foraminifera, etc.	20	210	Englishtown.
Dark, very slightly greenish micaceous clay with very little greensand. *Gryphaea* and *Belemnitella* at 240 to 250 feet.	40	250	Woodbury.
Still darker, almost black micaceous clay with yellowish pebbles between 270 and 290 feet. No fossils observed.	40	290	Do.
Decidedly greenish clay; contains at 290 to 300 feet some molluscan fossils similar to fossils at Lenola, but different from those observed in the overlying beds. Nodules at 290 to 310 feet.	40	330	Merchantville.
Medium coarse gray or bluish-white sand, abundantly water bearing; supplies well No. 3.	30	360	Magothy and Raritan.

From the above section the dip of the water-bearing formations from their outcrop is as follows: Mount Laurel-Wenonah sand 28 to 30 feet; Englishtown 34 feet; Magothy-Raritan 38½ feet.

In this well, as at the borough wells, the entire thickness of the green-sand marl is penetrated, and 10 feet of the lime-sand phase of the Vincentown is represented.

A well about 1 mile southeast of Auburn, on the road to Woodstown, furnishes the following record:

Record of well of Benjamin Cheesman at locality 20, near Auburn.

[Elevation, 100 feet; depth, 301 feet. Water rises within 100 feet of surface. Haines Bros., drillers.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Surface soil	2	2	[Quaternary and Tertiary.]
Clay and gravel	4	6	
Orange-colored sand, "molding sand"	8	14	
"Bullhead" boulder on green clay marl	1	15	
Light olive-colored greensand marl	10	25	[Hornerstown and Navesink ?]
Clay, gravel, and greensand mixed, dark olive color	10	35	
Lighter olive-colored greensand consisting of whitish quartz grains and glauconite grains.	10	45	
Reddish-yellow quartzose sand with a few greensand grains.	50	95	[Mount Laurel and Wenonah.]
Sandy, marly clay; a few greensand grains	20	115	
Reddish-yellow sand, same as above	10	125	
Olive-green clay and sand, white and red-stained quartz grains, and some glauconite grains.	20	145	[Marshalltown to Merchantville ?]
Gravelly conglomeratic mixture of whitish quartz grains and dark-blue mineral grains (vivianite); teeth and vertebra of shark.	10	155	
White sand and running black mud	25	180	
Dark clay marl, micaceous	87	267	
Medium sand, very slightly olive colored	23	290	[Magothy and Raritan ?]
Coarser sand, bluish white, with water	10	300	
Red and white mottled clay; colored water blood-red	1	301	

[a] New Jersey Geol. Survey Ann. Rept. for 1896, pp. 127-128, 1897.

The interpretation of this record is not very clear because of the general distribution of quartzose material. Some of this material from higher beds may have become mixed in drilling with material of lower beds. There seems to be, however, 30 feet of greensand marl overlain by 15 feet of overburden. This locality is about 2 miles from Point Airy railroad station and about 1 mile from Oldmans Creek, which, according to the map, seems large enough to utilize for transportation.

Two wells at Sharptown show similar but not identical records.

Record of well of William Richman at locality 21, Sharptown.

[About 500 feet north of upper bridge over Salem Creek. Elevation, about 10 feet; depth, 136 feet. C. C. Holladay, driller and informant.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Dug well	10	10	Quaternary and Tertiary?
Clay and sand	70	80	
Marl	31	111	Hornerstown and Navesink.
Quicksand	10	121	Mount Laurel and Wenonah.
Sand and gravel	15	136	

Record of well of Thomas McAllister at locality 22, Sharptown.

[About half a mile N. 29° W. from upper bridge over Salem Creek, east of road. Elevation, about 52 feet; depth, 155 feet. C. C. Holladay, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Soil and clay	20	20	Quaternary.
Red sand	30	50	Kirkwood?
Fine sand	20	70	Hornerstown and Navesink.
Green marl	30	100	
Shell marl	10	110	Mount Laurel and Wenonah.
Quicksand	45	155	

The city wells (locality 18) and those of the Ice & Cold Storage Co. (locality 19) lie in the Vincentown belt southeast of the greensand marl. The thickness of the greensand penetrated by these wells, 50 feet, may therefore be regarded as the maximum thickness for the district. The holes bored by the cooperating surveys (localities 12–14) lie within the greensand belt, near its margin, and show somewhat lower thicknesses, averaging 35 feet. In consideration of the thicknesses at the Sharptown wells (localities 21 and 22; 31 and 40 feet, respectively), this average seems a little low and may indicate a considerable erosion of the greensand at localities 12–14.

OTHER DATA.

Marl was formerly dug on the north side of Salem Creek about 0.15 mile west of the borough limits. This locality was considered as a drilling site for the present work but was given up because of the thickness of the overburden above the upper beds of marl.

Along Nihomus Run about 1.5 miles northwest of Woodstown (locality 23) the marl was formerly dug and used by many people. The following section was then exposed:[12]

Section of marl beds on Nihomus Run.

	Feet.
Yellow lime sand and yellow limestone	9
Shells	4–6
Green marl	15
Chocolate marl.	

These pits are not now operated, and they lie too far from the railroad to be commercially attractive.

At Oldmans Creek, about 3.5 miles from Woodstown, below the bridge on the road between Point Airy and Harrisonville, the lime sand is exposed in an old pit now largely filled with water. This locality is cited by Cook[13] as a place where the lime sand was well exposed and commonly dug.

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[12] Cook, G. H., Geology of New Jersey, p. 272, 1868; New Jersey Geol. Survey Ann. Rept. for 1886, p. 179, 1887.

[13] Cook, G. H., Geology of New Jersey, p. 273, 1868.

LIME SAND.

As shown on the map the lime sand beds on Nihomus Run come within about a quarter of a mile of the railroad. At that place they should be somewhat thicker than at the pits farther down the creek, because they are farther back down the dip. They have doubtless been somewhat eroded, but the three measurements given at Nihomus Run and in the wells at localities 18 and 19 show that a thickness of 10 feet or more of lime sand may be expected at Woodstown. No data regarding its quality are available, but inferences may be drawn from its former rather extensive use. The deposits on Salem Creek are crossed by the railroad and are probably the most accessible. At the city wells (locality 18) the lime sand is covered by 15 feet of overburden.

ESTIMATES OF TONNAGE AND VALUE.

The average thickness of the greensand marl in the 2.5-acre tract, as indicated on page 34, is about 32 feet. The average potash content, weighted according to the thicknesses represented by the respective samples, is 6.80 per cent. In computing this average the thicknesses employed for holes 6 and 7 were those of which the respective samples were considered representative, as indicated in the records of these holes. Thus in the 2.5-acre tract a bed of greensand 32 feet thick and containing 6.80 per cent of potash (K_2O) may be assumed. Here, as in the estimates for the Salem district, the weight of a cubic foot of greensand, 28 per cent being allowed for voids, is assumed to be 133 pounds. Under these conditions an acre at the selected site would contain $\frac{43{,}560\times32\times133\times0.068}{2{,}000}=6{,}300$ tons of potash (K_2O), and the 2.5 acres would contain 15,750 tons. On the assumption of a recovery of 80 per cent and a price of $2.50 per unit of 20 pounds (March, 1920) the potash in a ton of greensand would be worth $13.60, and the quantity in an acre of ground at the selected site would be worth $1,260,000. It seems unlikely that the price will long remain so high. At the more probable figure of $1.50 per unit the potash in a ton would be worth $8.16 and that in an acre would be worth $756,000. These values are hypothetical, because the potash must be recovered by processes not yet satisfactorily demonstrated.

The wells at localities 15, 18, and 19 show that a maximum thickness of 50 feet of greensand marl may be expected in the vicinity of Woodstown. Northwestward the thickness diminishes to zero because of the gentle southeasterly inclination of the beds and the beveling effects of erosion. Thus at Woodstown, as at Salem, the greensand in considerable thickness underlies broad areas. The 2.5-acre tract may, in the light of the analyses from other districts, be considered as representative for this district.

UTILIZATION OF THE DEPOSITS.

The overburden in the sample area averages about 10 feet in thickness. Farther east it is undoubtedly thicker. To the west the overburden is irregularly distributed, and its thickness would have to be determined for any given locality but should not be excessive within the area mapped as greensand.

The analyses show that the higher and lowermost beds have somewhat less potash than the middle beds but that practically all are usable. Water stands in the holes within a few feet of the surface and would have to be considered in any plan for mining the greensand.

The railroad offers at present the most feasible means of transportation. The map shows several sites that could be utilized along the railroad from Woodstown northward toward Swedesboro.

Salem Creek below Courses Landing and the canal to the Delaware are now used by barges for general freighting. Between Courses Landing and Sharptown the creek is shallower but might perhaps be used by boats or scows of lighter draft. The hills south of the creek and west of Sharptown apparently afford good thicknesses of marl within reach of water transportation.

MULLICA HILL.

The steep bluff just east of the railroad station at Mullica Hill (locality 24) has long been known for its excellent exposure of the basal bed of the Navesink marl and for its numerous fossils. The section (see Pl. VI, *B*) is as follows:

Section of Navesink marl near station at Mullica Hill.

	Feet.
Greensand marl, loose, dark green	7±
Shell bed with more or less coherent matrix of marl and quartz sand	3–4
Yellow sand	4
Reddish-brown sand to road level	15±
	30±

The two lower beds are overwashed with marl from above and are hence dark colored. The veneer of marl may be removed by scraping with the foot and the yellow sands (Mount Laurel) exposed. Many of the shells are as much as 4 or 5 inches in diameter.

Marl was formerly dug at several places near Mullica Hill and was favorably regarded, perhaps because of its relatively high content of phosphoric acid, which, according to two analyses cited by Cook,[14] ran as high as 3.48 and 3.60 per cent. A sample taken by W. C. Phalen on the Henry Edwards place, 2 miles southwest of Mullica

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[14] Cook, G. H., Geology of New Jersey, p. 437, 1868.

Hill, was analyzed in the laboratory of the United States Geological Survey and found to contain 7.15 per cent of potash. The greensand at this locality is 5 feet or more thick and is overlain by 15 to 20 feet of clay and gravel.[15] In 1916 some 50 tons of marl was shipped for experimental purposes from the pits of Mrs. E. B. Sharp (locality 25), about 1.15 miles S. 64° E. of Mullica Hill station. The lime sand also occurs in the same vicinity.

Several localities near Mullica Hill and Jefferson station were visited with the idea of selecting a drilling site, but the overburden in places sufficiently near the railroad proved to be too thick to permit hope of commercial development.

SEWELL DISTRICT.

The pits near Sewell have long been known for their excellent marl, which was used as a fertilizer. More recently it has been used for experiments in extraction of potash. Excellent railroad facilities are available, and there are extensive areas of relatively even ground in which the overburden does not seem excessive. The actual area drilled at Sewell included only 2.5 acres, but data for a number of localities within a radius of 3 or 4 miles of Sewell are available and may conveniently be discussed in connection with the results of the borings of the cooperating surveys. These localities are therefore included in the Sewell district.

EDWARDS RUN.

Relatively recent observations by the State geologist on branches of Edwards Run 2 to 3 miles west of Sewell show the exposures described below.

At locality 26 an old marl pit at an elevation of about 70 feet shows the upper part of the combined Hornerstown and Navesink beds.

Section in road cut at locality 27.

	Feet.
Pleistocene gravel (Bridgeton).	
Kirkwood, thin layer.	
Vincentown	2–3
Terebratula bed, base of Vincentown, elevation 75 feet.	
Hornerstown marl.	

Section in old pit near ice house at locality 27, north of road.

	Feet.
Kirkwood formation	4
Vincentown sand	5–6
Hornerstown marl.	

At a pit near the pond just north of locality 27 and slightly lower there is a good exposure of Hornerstown marl but no Vincentown.

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[15] Ashley, G. H., Notes on the greensand deposits of the eastern United States: U. S. Geol. Survey Bull. 660, pp. 39, 47, 1918.

Section along road at locality 28.

	Feet.
Pleistocene gravel.	
Miocene clay, Kirkwood	2
Vincentown, more or less marly	5
Terebratula shell bed, elevation about 70 feet.	
Hornerstown marl down to flood plain	15±
	22±

These exposures are typical of the partial sections available here and there through the marl belt.

BARNSBORO.

Several well records give an idea of the thickness of the marl and its overburden near Barnsboro.

Record of well of John Shutes, near Barnsboro.[a]

[Elevation, 120 feet; depth, 140 feet; water rises within about 50 feet of surface.]

	Thickness	Depth.	Formation.
	Feet.	*Feet.*	
Whitish quicksand	55	55	[Kirkwood?]
Greensand marl	35	90	[Hornerstown and Navesink.]
Chocolate marl	15	105	
Shell rock	2	107	
Dark sand	10	117	[Mount Laurel and Wenonah.]
White gravel with water	23	140	

[a] New Jersey Geol. Survey Ann. Rept. for 1896, p. 131, 1897.

Record of wells of Dilks Bros., locality 29, near Barnsboro.[a]

[About half a mile south of crossroads in Barnsboro; two wells; elevation, about 100 feet; depths, 110 and 170 feet. Haines Bros., drillers.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Surface soil	5	5	
Orange-colored sand	34	39	[Kirkwood?]
Dark clay; "no greensand nor other microorganisms"	[b] 5	[b] 40	
Light-green marl	20	60	[Vincentown(?) to Navesink.]
Rusty green marl; lower 10 feet with coarser quartzose sand grains.	25	85	
Gray sand with a few clay seams; *Belemnites* at 95 and 105 feet; abundance of water at 110 feet.	70	155	
Muddy sandy clay	15	170	

[a] New Jersey Geol. Survey Ann. Rept. for 1896, p. 130, 1897.
[b] Record evidently erroneous.

J. L. North kindly furnished records for the wells of Charles Dilks and Isaac Dilks, said to be 175 and 135 feet deep respectively. As the two records are similar only the first is given.

Record of well of Charles Dilks, at locality 29a, three-fourths of a mile south of Barnsboro.

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Yellow fine molder's clay	40	40	Kirkwood (?).
Marl	60	100	Vincentown (?) to Navesink (?)
Shale	5	105	
Black and white pepper sand	35	140	Mount Laurel and Wenonah.
Coarse green sand	35	175	

This record differs considerably from the previously published record of the same well given above. It may be noted, however, that the *Belemnites*, a form characteristic of the basal part of the Navesink, which occurs at 105 feet in the first record, corresponds in position with the base of the shale in the second record, and that in both records marl begins at 40 feet. Either the marl is unusually thick or it includes a glauconitic portion of the Vincentown sand.

Record of well of Dr. W. P. Chalfont at locality 30, Barnsboro.

[Depth, 149 feet. J. L. North, driller and informant.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Yellow gravel, very hard	28	28	Pleistocene.
Fine yellow quicksand	35	63	Kirkwood.
Marl and shale	50	113	Hornerstown and Navesink.
Hard shale	30	143	Mount Laurel and Wenonah (?).
Greensand; plenty of good water	6	149	

A well at locality 31, about a quarter of a mile farther west, sunk by J. L. North for James Tomlin, gave a similar record.

Record of well of James Jessup at locality 32, near Barnsboro.[a]

[About 1 mile northwest of Barnsboro, on road to Mount Royal station. Elevation, 70 feet; depth, 318½ feet; water rises within 70 feet of surface. Joseph Pratt, driller.]

	Thickness.	Depth.
	Feet.	*Feet.*
Surface loam	5	5
Greenland [b]	30	35
Black mud and marl alternating in 8 to 10 foot layers; a little water at 90 and 100 feet	80	115
Black mud	183	298
Fine white sand	5	303
Coarse white gravel with water	15½	318½
Stopped on dark quicksand.		

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[a] New Jersey Geol. Survey Ann. Rept. for 1897, p. 256, 1898.

[b] The "greenland" is the lower marl, as shown by the occurrence of *Belemnites* and *Exogyra* on the banks of a small creek a few hundred feet to the west.

J. L. North furnishes the following record for the well of James Jessup. The discrepancy between the two records illustrates a difficulty sometimes experienced in trying to procure accurate well data. From either record it is evident, however, that greensand marl in commercial quantity is probably present.

Record of well of James Jessup, near Barnsboro.

[Elevation, 90± feet; depth, 333 feet; according to J. L. North, informant.]

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	3	3
Marl	80	83
Black clay	200	283
Fine black sand	40	323
Coarse greenish-gray sand	10	333

HOLES 8 TO 10.

Three holes, Nos. 8 to 10, were sunk on the property of the West Jersey Marl & Transportation Co. east of the railroad track half a mile south of the station. Their location is indicated on the map of the company's property (fig. 4), drawn about 1890 by J. C. Voorhies, secretary, and kindly loaned by him for use in this report. The records of these holes follow.

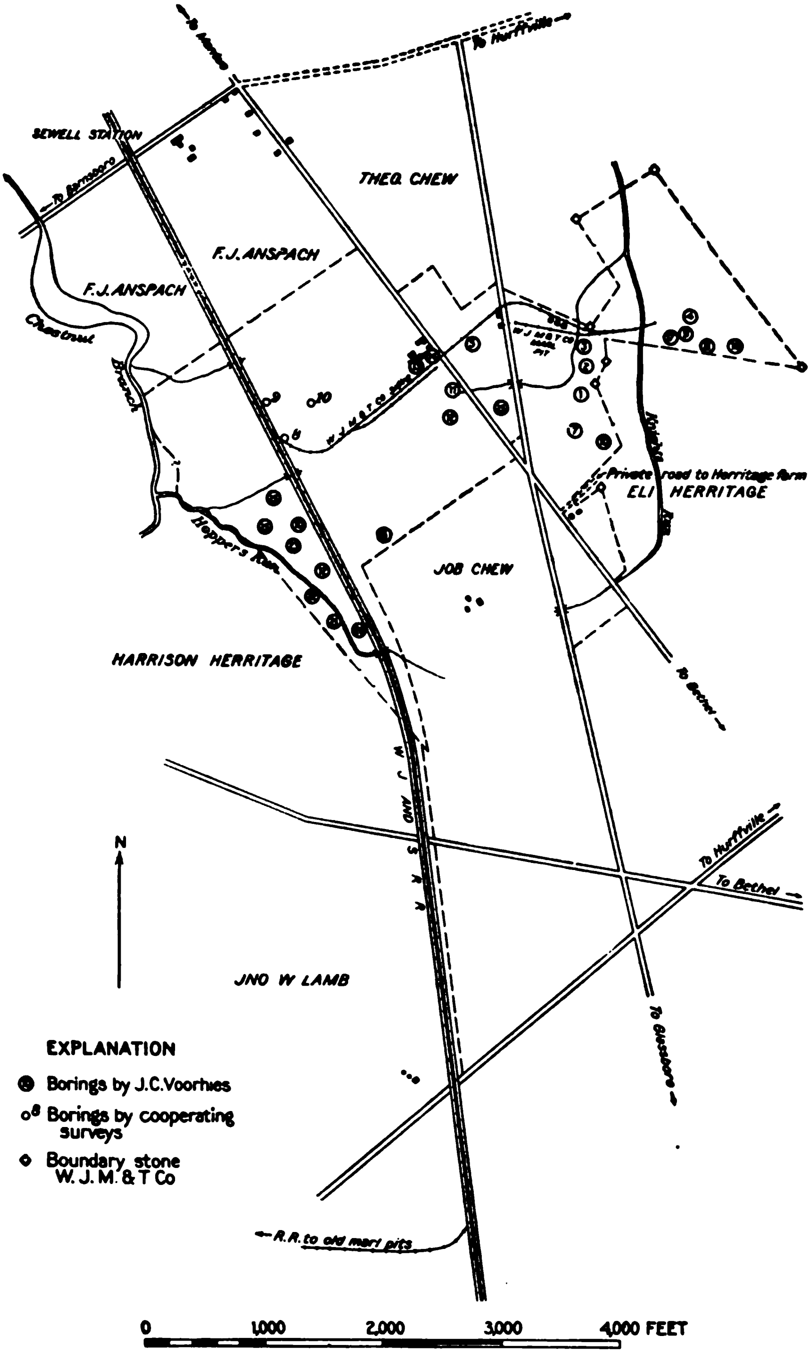

FIGURE 4.—Map of the property of the West Jersey Marl & Transportation Co. and adjoining property near Sewell station. After J. C. Voorhies.

Records of holes in Sewell district.

Locality 33, hole 8.

[Property of West Jersey Marl & Transportation Co., at Sewell, 2,750 feet southeast of center line of railroad station and 40 feet east of center of track. Elevation of surface, about 70 feet. R. K. Bailey, analyst. S. J. Taylor and J. L. North, drillers.]

	Thickness.	Depth.	Field No. of sample.	K_2O.	Formation.
	Ft. in.	*Ft. in.*		*Per cent.*	
Top soil, drab-gray sandy clay, with few pebbles.	1	1	....	....	Recent.
Clay, fine, sandy, grayish buff at top, with a few subangular pebbles as much as 2 inches in diameter. Fewer pebbles and deeper-yellow color in lower part.	1	2	....	....	Pleistocene.
Sand, very fine, very clayey and micaceous, with considerable ocher; finely bedded; white sandy streaks occur in the yellow to deep orange colored material; water bearing at base.	8 10	10 10	....	....	Kirkwood.
Glauconite bed, grayish to olive green and clayey.	1	10 11	M-29	3.54	Hornerstown.
Sand composed of quartz and glauconite........	2	11 1			
Glauconite beds, grayish green, clayey..........	11	12			
Glauconite beds, yellow olive, very clayey......	2 4	14 4	M-30	4.54	Do.
Glauconite beds, olive green, very clayey and stiff; contain yellow specks of iron oxide. Sample M-31 collected dry in driven cylinder; M-32 collected wet in trough as check.	11	15 3	M-31 M-32	5.99 5.92	Do. Do.
Glauconite beds, very clayey, yellow olive; upper 2 inches contains considerable yellow oxide of iron.	4 3	19 6	M-33	6.70	Do.
Glauconite beds, blackish to grayish green, with considerable clay.	5 6	25	M-34	7.25	Do.
Glauconite beds like last (?)...................	1	26	M-35	7.40	Do.
Glauconite beds, stiff, with much light-green clay. Material in this interval became mixed with overlying yellowish material by accident in driving pipe. This interval therefore excluded from samples.	1	27	....	....	Do.
Glauconite beds, upper part light green and stiff. At about 30 feet become more mealy in texture, with larger proportion of glauconite, and contain a few pieces of shell. Sample M-36 taken by core tool; M-36a, same interval, material collected wet as check.	5	32	M-36 M-36a	7.71 7.36	Do. Do.
Glauconite beds, similar to above, not sampled..	1	33	....	....	Navesink.
Glauconite beds, brownish black or chocolate-colored, coarser textured, one rounded pebble half an inch in diameter noted.	6	33 6	M-37	6.36	Do.
Glauconite beds, brown, with some mingling of green; transition beds.	6	34	M-37a	7.62	Do.
Glauconite beds, chocolate-colored, with some intermingling of green. Sample M-38 taken dry with core tool; M-38a taken wet as check.	2	36	M-38 M-38a	6.41 6.18	Do. Do.
Glauconite beds, brownish to black, similar to last, water bearing.	5	41	M-39	6.88	Do.
Glauconite beds, similar to last but contain few gravel grains and an increasing proportion quartz sand.	2 3	43 3	M-40	5.59	Do.
Glauconite beds, black to grayish black; contain considerable quartz sand and the rice gravel but little or no shell.	5 3	48 6	M-41	3.51	Do.
Glauconitic sand like last.....................	4	48 10	....	....	Do.
Shell bed, gravel, quartz sand, glauconite, and large pieces of *Gryphaea*, *Exogyra*, *Belemnitella*, concretions of vivianite.	3	49 1	....	....	Do.

Locality 34, hole 9.

[Property of West Jersey Marl & Transportation Co., 330 feet N. 20° W. from hole 8. Elevation of surface, about 70 feet. R. K. Bailey, analyst. J. L. North, driller.]

	Thickness.	Depth.	Field No. of sample.	K_2O.	Formation.
	Ft. in.	*Ft. in.*		*Per cent.*	
Top soil, brownish drab, clayey sand, fine texture.	1	1	....	....	Recent.
Sand, clayey, with scattered pebbles 2½ inches in diameter; matrix very fine textured, with floury feel and yellow color.	6	1 6	....	....	Pleistocene.
Sand, clayey like last, with scattered gravel grains.	1 10	3 4	....	....	Do.
Sand, clayey, very fine, micaceous, finely bedded, leafy texture, orange colored, with some white coarser sand infiltered in cracks.	2 7	5 11	....	....	Kirkwood.
Sand similar to last but light gray............	2 4	8 3	....	....	Do.
Glauconite beds, yellowish olive, stiff clayey material, with considerable yellow oxide of iron.	1 8	9 11	M-42	4.97	Hornerstown.
Glauconite beds, deep olive, stiff, clayey, upper 3 or 4 inches oxidized like M-42 but remainder with uniform texture and color.	5	14 11	M-43	6.73	Do.
Glauconite bed like last........................	1	15	M-44	6.81	Do.
Glauconite beds, somewhat less clay, more mealy texture, some darker streaks and a few pellets of chocolate-colored clay.	2	17			
Glauconite beds, distinctly darker, more mealy texture, more nearly pure glauconite grains.	4	17 4			
Glauconite beds, dark green to blackish, mealy texture, water bearing in lower part.	5 2	22 6	M-45	7.43	Do.
Glauconite beds, similar to M-45..............	4 2	26 8	M-46	7.90	Do.
Glauconite beds, chocolate marl, brownish drab with greenish tint, transition beds; considerable clay with scattered ferruginous particles and ferruginous masses, probably pieces of replaced shell.	3 3	29 11	M-47	7.13	Navesink.
Glauconite beds similar to M-47 but without the greenish tint, brownish black, stiff clayey material.	5 9	35 8	M-48	6.74	Do.
Glauconite beds similar to M-48 but containing greenish streaks.	5 3	40 11	M-49	5.90	Do.
Glauconite beds similar to M-49...............	1	41	M-50	3.47	Do.
Glauconite beds similar to M-49 but containing considerable quartz sand and some small gravel	2 7	43 7			
Glauconite beds like last but with pieces of shell and broken casts composed of glauconitic material, rice gravel.	5	44			

Locality 35, hole 10.

[Property of West Jersey Marl & Transportation Co., about 375 feet N. 44° E. from hole 8. Elevation of surface about 69 feet. R. K. Bailey, analyst. J. L. North, driller.]

	Thickness.	Depth.	Field No. of sample.	K_2O.	Formation.
	Ft. in.	*Ft. in.*		*Per cent.*	
Top soil, brown loam	8	8	....	....	Recent.
Gravel, at first scattered pebbles in light-yellow matrix of clayey sand, then darker-yellow coarser sand with pebbles as large as 2 inches in diameter, water bearing.	2 11	3 7	....	....	Pleistocene.
Sand, yellow and gray banded, fine textured, clayey and micaceous, becoming purplish in lower 6 inches.	4 1	7 8	....	....	Kirkwood.
Glauconite beds, blackish green, rather stiff with clay, no oxidized layer or olive-green bed as at holes 8 and 9. Three pebbles discarded as having probably followed down pipe.	1	8 8	M-51	3.83	Hornerstown.
Glauconite beds, deep bluish to grayish green, less clay than M-51.	6 4	15	M-52	6.60	Do.
Glauconite beds, dark or grayish green, mealy textured, similar to M-52 but lower 6 inches lighter green.	5	20	M-53	7.63	Do.
Glauconite beds similar to M-53	4 7	24 7	M-54	7.52	Do.
Glauconite beds, chocolate marl, brownish black with some streaks of green material, fairly coarse texture but with considerable clay.	6	25 1	M-55	6.85	Navesink.
Glauconite beds, chocolate marl	7 4	32 5	M-56	6.57	Do.
Glauconite beds similar to M-56 but containing a few grains of gravel, small marcasite concretions, and considerable brown clay.	3 3	35 8	M-57	6.90	Do.
Glauconite beds similar to above but containing fragments of shell, clay pellets, and somewhat larger proportions of gravel.	9	36 5			
Glauconite beds becoming increasingly sandy. At base consist of glauconite with quartz sand, brown clay, concretions, small fragments of shell, and crystals of vivianite.	1 2	37 7	....	....	Do.
Glauconite beds, compact, hard mixture of clay, quartz sand, and glauconite with gravel grains.	2 5	40	....	....	Do.
Glauconite beds similar to above but somewhat softer. Rice gravel and quartz sand in increasing proportion.	2 7	42 7	....	....	Do.
Glauconite beds similar to last but with fragments of shell and pepper and salt color. At base fragments of *Belemnitella* appear.	5	43	....	....	Do.

For comparison with other borings in the vicinity the data of holes 8 to 10 are summarized in the following table:

Thickness and quality of greensand beds at holes 8 to 10, Sewell.

Hole.	Bed.	Sample.			Thickness of bed.	Average content of K_2O.[a]
		No.	Thickness represented.	K_2O.		
			Ft. in.	*Per cent.*	*Ft. in.*	*Per cent.*
8	Overburden	....	....	....	10 10	....
	Bank marl	M-29	1 2	3.54	8 8	5.61
		M-30	2 4	4.54		
		M-31-2	11	5.96		
		M-33	4 3	6.70		
	Green or blue marl	M-34	5 6	7.25	13 6	[b] 7.40
		M-35	1	7.40		
		....	1	....		
		M-36, 36a	6	7.54		
	Chocolate marl	M-37, 37a	1	6.99	15 10	[c] 5.48
		M-38, 38a	2	6.30		
		M-39	5	6.88		
		M-40	2 3	5.59		
		M-41	5 3	3.51		
		....	4	....		
9	Overburden	....	....	....	8 3	....
	Bank marl	M-42	1 8	4.97	9 1	6.33
		M-43	5	6.75		
		M-44	2 5	6.81		
	Green or blue marl	M-45	4 2	7.43	9 4	7.64
		M-46	4 2	7.90		
	Chocolate marl	M-47	3 3	7.13	17 4	5.98
		M-48	5 9	6.74		
		M-49	5 3	5.90		
		M-50	3 1	3.47		
10	Overburden	....	....	....	7 8	....
	Bank marl	M-51	1	3.83	7 4	6.22
		M-52	6 4	6.60		
	Green or blue marl	M-53	5	7.63	9 7	7.58
		M-54	4 7	7.52		
	Chocolate marl	M-55	6	6.85	13	[d] 6.69
		M-56	7 4	6.57		
		M-57	4	6.90		
		....	1 2	....		
	Average:					
	Overburden	....	....	....	8 11	
	Bank marl	....	....	....	8 4	[e] 6.09
	Green or blue marl	....	....	....	10 10	[e] 7.52
	Chocolate marl	....	....	....	15 5	[e] 5.99
					34 7	[f] 6.49

[a] Average for bed weighted according to the thicknesses represented by the respective samples.

[b] Average for 12 feet 6 inches.

[c] Average for 15 feet 6 inches.

[d] Average for 11 feet 10 inches.

[e] Average for bed in 2.5-acre tract weighted according to thicknesses at the respective holes.

[f] Average of entire thickness of marl in 2.5-acre tract.

BORINGS OF WEST JERSEY MARL & TRANSPORTATION CO.

Record of borings of West Jersey Marl & Transportation Co., near Sewell.

Locality.[a]	Over-burden.	Bank marl.	Green marl.	Locality.[a]	Over-burden.	Bank marl.	Green marl.
	Ft. in.	*Ft. in.*	*Ft. in.*		*Ft. in.*	*Ft. in.*	*Ft. in.*
1	14 0	12 6	8 0	15	12	12	7
2	18	9	7	16[b]	22	....	....
3	21	0	7	17	6	0	6
4	18	13	7	18	19	14	7
5	12	12	6	19	19	15	7
6[b]	21	....	....	20	6	11	7
7	15	14	7	21	9	12	7
8	21	10	6	22	8	4	7
9	12 6	9 6	7	23	5	5	7
10	16	13 6	7	24	5	5	7
11	10	11	7	25	16	14	7
12	16	12	7				
13	13	11	7	Average	13 10	[c]10 1	[c]6 11
14	12	12	7				

[a] Locality numbers refer to figure 4. [b] Did not reach marl. [c] Average for 23 localities.

These holes all stopped at or above the chocolate marl, which, because of its astringent qualities, was not considered desirable for agricultural use. The analyses of the chocolate marl at holes 8 to 10 show that it contains less potash than either the bank marl or the green marl but probably enough for commercial recovery by any process operative for the other two beds.

The average thickness of the overburden in the borings made by the company is nearly 2 feet greater than that for the 2.5-acre tract represented by holes 8 to 10, and that of the bank marl 1 foot 9 inches greater, but that for the green marl is nearly 4 feet less.

SEWELL MARL PIT.

The large pit belonging to the West Jersey Marl & Transportation Co. is shown in figure 4 and as locality 36 on Plate I. Much of the pit is now overgrown and more or less slumped, but marl has been dug at the northwest corner (see Pl. VIII, *B*), where the following section is exposed and available for sampling.

Section of pit of West Jersey Marl & Transportation Co., near Sewell (locality 36).

[R. K. Bailey, analyst.]

	Thickness.	Depth.	Field No. of sample.	K_2O.
	Ft. in.	*Ft. in.*		*Per cent.*
Old filling	5 9	5 9	....	....
Grayish-green (bank) marl	1	6 9	....	....
Grayish-green marl	4 9	11 6	M-59	7.64
Dark-green marl	1 6	13	M-61	7.89
Dark bluish-green marl	1	14	....	....
Dark bluish-green marl	6	14 6	M-60	7.88
Dark bluish-green marl	1	15 6	....	....
Dark chocolate-brown marl	6	16	M-62	6.73
General sample run of mine, blue to gray	....	....	M-63	7.80

The samples were collected as typical of the freshly dug material of the respective kinds. The analyses run higher than the average of the analyses of samples of similar beds from holes 8 to 10, though they are matched by analyses of individual samples from those holes. Probably all the marl now dug in this pit corresponds with the green marl at holes 8 to 10. None of the stiff, clayey olive-green marl found at those holes appears in the sampled part of the pit.

The overburden at older exposures on the east and southeast sides of the pit is 12 to 15 feet thick and includes a little Kirkwood sand beneath the Pleistocene sand and gravel. Locally a thin bed of sand and gravel cemented with oxide of iron (ironstone) occurs beneath the Pleistocene. Westward from the pit the overburden increases to 10 or 15 feet.

WELL DATA.

Several wells in the vicinity of Sewell give further data on the thickness of the marl and the amount and character of the overburden. They also indicate water-bearing beds, which might be of use to companies interested in developing the marl. The writer is indebted to M. W. Twitchell for the following record of the well of F. J. Anspach.

Record of well of F. J. Anspach, near Sewell (locality 37).

[On Chews Hill, east of the Mantua road. Elevation, 82 feet; depth, 432 feet.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Yellow gravel, sand, and sandy clay	17	17	Pleistocene.
Green marl	7	24	Hornerstown and Navesink.
Black or very dark-green marl	6	30	
Reddish-yellow sandrock, with casts of shells	13	43	
Yellowish sand, with some marl	13	56	
Light-yellow sand, with some marl, water bearing; water strongly impregnated with iron.	16	72	Mount Laurel and Wenonah.
Light-yellow sand	32	104	
Tough fine blue clays and blue sandy clay; some *Exogyra* shells at 180 feet, a thin layer of sand at 264 feet, a very sandy clay with some large pebbles at 276 feet, and a sandy clay with finely broken shells at 280 feet.	180	284	Marshalltown, English town, Woodbury, Merchantville.
Greenish sand	20	304	
Greenish to gray sands; streak of clay at 335 feet	31	335	Magothy and Raritan.
Fine clean gray sand	7	342	
Coarse sandy gravel, angular grains; yielded a little water	9	351	
Stiff white clay	1	352	
Fine gray sand with clay streaks and considerable lignite	23	375	
Layers of white sand and white clay	6	381	
White angular gravel, coarse; much water	14	395	
Extra coarse gravel	10	405	
Fine white sand; water	3	408	
Fine sand, mixed with coarse gravel; water	7	415	
Very coarse gravel, up to cobblestones	5	420	
Hard white clay	12	432+	

The water at 405 to 420 feet is utilized and is reported as pure, soft, and satisfactory in every respect. On pumping 40 gallons a minute the water stands at 77 feet below the surface.

The record shows 39 feet of the combined Hornerstown and Navesink marls beneath an overburden of 17 feet of gravel, sand, and clay.

Record of well of J. L. North, at Sewell (locality 38).

[About 0.21 mile N. 76° E. of railroad station, in angle formed by two streets. Elevation, about 82 feet; depth, 336 feet. J. L. North, informant.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Coarse yellow sand	10	10	Pleistocene.
Fine yellow sand	30	40	Kirkwood (?).
Marl	38	78	Hornerstown and Navesink.
Shale, marly, with some shells	20	98	
Yellow gravel; very irony water	23	121	Mount Laurel and Wenonah.
Tough chocolate-colored clay	200	321	Marshalltown to Merchantville.
White quartz sand with considerable "hard coal" (glauconite?) about the size of buckwheat; water rose within 68 feet of surface.	15	336	Magothy (?).

The overburden at this well is 40 feet thick, and the marl apparently 58 feet thick.

A well sunk for George B. Hurff at locality 39, near the North well, shows a similar record.

The well of David T. Locke at locality 40, in the same general vicinity, shows a somewhat different record.

Record of well of David T. Locke, at Sewell (locality 40).

[J. L. North, driller and informant.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Greenland clay	25	25	Pleistocene (?).
Sand	10	35	Kirkwood (?).
Blue marl	25	60	Hornerstown and Navesink (?).
Chocolate-colored shale	11	71	
Greensand; plenty of water	14	85	Mount Laurel (?).

The "greenland clay" is probably reworked glauconitic material. The well may stop in the lower Navesink but probably stops in the top of the Mount Laurel. With these interpretations there would be 35 feet of overburden and nearly 50 feet of marl. If this location is correct the little knoll north of the well should be included in the greensand belt instead of with the pre-Navesink formations as mapped.

A test well sunk near Sewell for the town of Woodbury gives a record interpreted by Twitchell as follows:

Record of well for town of Woodbury, near Sewell (locality 41).

[About three-fourths of a mile northeast of Sewell along strike of formations. Elevation, 13 feet (?); depth, 283 feet. Artesian Well Drilling Co., driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Meadow mud	12	12	Recent.
Sandy mud	63	75	Hornerstown and Navesink.
Fine sand	7	82	Mount Laurel and Wenonah.
Sticky clay	153	235	Marshalltown to Merchantville.
Medium sand	48	283	Magothy and Raritan.
Clay	....	....	

The town of Woodbury now has in this vicinity a group of eight 10-inch wells, according to J. L. North, who has kindly indicated their positions as shown on the map (Pl. I). As above interpreted the thickness of the overburden is not excessive, but the thickness of the marl is unusual.

The records and locations of the three following wells were furnished by J. L. North.

Record of well of John Schmidt, near Salina (locality 41a).

[Elevation, about 60 feet.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Yellow sand	14	14	Kirkwood (?) and Vincentown.
Gray marl	10	24	
Blue marl	40	64	Hornerstown and Navesink (?).
Shale full of shells	30	94	
Black marl	7	101	
Hard shale	2	103	
Coarse green sand full of shells	14	117	Mount Laurel and Wenonah (?).

From the location of the well there is little doubt that the gray marl and perhaps much of the overlying sand is Vincentown. Possibly part of the "blue marl" may be a more glauconitic phase of the Vincentown, for the marl here seems unduly thick. The base of the Navesink is not distinguished but may be represented by the "hard shale." The "coarse green sand" is probably the water-bearing Mount Laurel and Wenonah sands, which are locally more or less glauconitic.

Record of well of Thomas Burroughs, near Hurffville (locality 41b).

[Elevation, about 90 feet.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Gravel	10	10	Pleistocene.
Yellow fine sand	50	60	Kirkwood.
Green marl	60	120	Vincentown(?) to Navesink.
Shale	4	124	
Gray sand	6	130	
Shale	2	132	
Green coarse rice gravel full of *Belemnites*	15	147	Mount Laurel and Wenonah.

This record corresponds fairly well with the preceding. The Vincentown is not distinguished but is probably present.

Record of well of Felix Behl, at Fairview (locality 41c).

[Elevation, about 125 feet.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Coarse gravel	28	28	Pleistocene.
Yellow sand	35	63	Kirkwood (?).
Green marl	30	93	Hornerstown and Navesink.
Very fine black and white sand	40	133	Mount Laurel and Wenonah (?).
Green clay	23	156	
Hard shale	5	161	
Coarse white sand	14	175	

The formations are not clearly distinguishable from these records, but they indicate the continuity of the marl in considerable thickness, though the overburden is heavy.

Two wells at Pitman show the amount and character of the overburden and the thickness of the marl in that district.

Record of well in camp-meeting grounds at Pitman (locality 42).[a]

[About one-third of a mile southwest of railroad station, on nearly the lowest ground in the area, at west edge of grove. Elevation, 110 feet. Haines Bros., drillers.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Surface soil, etc	10	10	[Quaternary.]
Orange-colored sand and sandy clay	60	70	[Tertiary.]
Dark clay, nearly black	10	80	
Bryozoan lime sand	20	100	[Vincentown.]
Greensand marl with Foraminifera and fragments of shell, probably *Terebratula*.	10	110	[Hornerstown and Navesink.
Greensand marl, less shell	10	120	
Clayey greensand	10	130	
Clayey sand	10	140	
Clayey marl, *Belemnites* and ponderous shells	10	150	
Yellowish sand with some clay, *Belemnites* and fragments of shell.	30	180	[Mount Laurel and Wenonah.]
Medium coarse clear sand with water	10	190	

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[a] New Jersey Geol. Survey Ann. Rept. for 1896, p. 128, 1897.

A well sunk for the town of Pitman on the east side of the railroad at locality 43, not far from the well just described, was drilled to a depth of 507 feet. For the first 190 feet its record was practically identical with the other.[16]

A third well drilled in the same general vicinity, for R. H. Corney, started at an elevation of 130 feet and penetrated bryozoan lime sand between depths of 115 and 125 feet. Greensand was found between depths of 125 and 160 feet, and coarse water-bearing gravels from 160 to 180 feet.[17]

These wells show that at Pitman lime sand 10 to 20 feet thick and greensand 35 to 50 feet thick lie beneath Tertiary and Quaternary deposits from 70 to 115 feet or more thick.

OTHER DATA.

The Kern pits, which lie on the east side of Chestnut Branch, about 1.5 miles above Sewell (locality 44), were visited in 1917 by Dr. Kümmel, from whose notes the following data were obtained. There is a very large opening, and the floor is overgrown with trees 6 inches or more in diameter. The bank is very high. Marl probably rises about 5 feet above the floor. Where the pit is most swampy the marl has 15 to 25 feet of overburden consisting of about 10 feet of yellow gravel, underlain by Kirkwood sand.

On the map of 1866 is shown a railroad running to these pits and marked "W. J. R. R." In the annual report of the State geologist for 1886, page 178, it is stated that "southeast of Barnsboro in Gloucester County, on the south branch of Mantua Creek, are important marl pits, one of which is worked by the West Jersey Marl Co. in a layer containing 12 feet of green marl."

Near the lower bridge over Bees Branch (locality 45) a pit owned by Howard Davis was in operation in September, 1917, when visited by Dr. Kümmel, who observed the following section:

Section of marl pit of Howard Davis, on Bees Branch near Sewell (locality 45).

[Elevation of surface, about 60 feet.]

	Feet.
A. Yellow sand and gravel	5-7
B. Brown marly sand with obscure casts of *Terebratula harlani* stained reddish brown locally	2
C. Reddish-brown to black marl with dark-green more or less mottled marl, purer at base	2
D. Green marl; locally streaks with discontinuous irregular lines of light chocolate-colored clay, only a minor feature. At 3 inches from top iron-incrusted seam. Basal 2 feet is blacker than upper part	6½
	17½

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[16] New Jersey Geol. Survey Ann. Rept. for 1901, p. 85, 1902.

[17] Idem, p. 84.

In digging layers A, B, and C are thrown away. The base of layer D is the level of the uneven floor. Marl is dug in layer E, 8 feet below this level, but at the time when these observations were made only layer D was being taken. Near by was a worked out pit in layer E full of water. When visited in November, 1918, by Dr. Kümmel and the writer the Davis pit was inactive and badly slumped.

On the William Wenzell place, just west of Sewell, 10 feet of greensand is overlain by 8 to 10 feet of clay and gravel. A sample of the greensand collected by W. C. Phalen was analyzed in the laboratories of the United States Geological Survey and found to contain 7.09 per cent of potash.[18]

LIME SAND.

At locality 46, south of the road from Sewell to Barnsboro and west of the creek, there is an exposure of 3 to 4 feet of lime sand. At locality 47, near Hurffville, some old pits in the Vincentown sand were visited in 1915 by Dr. Kümmel, who found them slumped and overgrown. In a circular published in 1903 these pits were cited as a good locality, and in the annual report of the State geologist for 1886, page 178, a section measured at these pits showed 9 feet of lime sand and 13 feet of greensand marl. These two localities furnish the exposures of the lime sand nearest to Sewell. It probably underlies the surface from half a mile to a mile south of the West Jersey Marl & Transportation Co.'s pit, but the overburden is doubtless thicker than 15 feet. No data regarding the quality of this lime sand are available.

ESTIMATES OF TONNAGE AND VALUE.

From the data given on page 50, the average thickness of the marl in the 2.5-acre tract near Sewell may be taken as 34 feet and its average potash content as 6.50 per cent. On the assumption, as in previous estimates, that the weight of the greensand, 28 per cent being allowed for voids, is 133 pounds per cubic foot, an acre in the specified tract would contain $\frac{43,560 \times 34 \times 133 \times 0.065}{2,000} = 6,400$ tons of potash (K_2O), and the 2.5 acres would contain 16,000 tons. With an 80 per cent recovery and a price of $2.50 per unit of 20 pounds (March, 1920), the potash in a ton of greensand would be worth $13 and that in an acre of ground would be worth $1,280,000. At the more probable price of $1.50 per unit the same quantities of potash would be worth $7.80 and $768,000, respectively. The values given for the potash are purely hypothetical, as they are dependent

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[18] Ashley, G. H., Notes on the greensand deposits of the eastern United States: U. S. Geol. Survey Bull. 660, pp. 40, 47, 1918.

upon successful extraction of the potash by processes not yet commercially demonstrated.

As previously explained, the marl beds are beveled off by erosion along the north boundary of the belt, but along the southeast border their thickness is probably as much as 50 feet. The well records and other data indicate that greensand marl is present, except where locally eroded, throughout the portion of the belt included in the Sewell district and that it may be expected to maintain a fairly uniform thickness along the strike.

UTILIZATION OF THE DEPOSITS.

The thickness of the overburden in the 2.5-acre tract averages about 9 feet. At the borings made by the West Jersey Marl & Transportation Co. the average thickness of the overburden was about 14 feet. Thus in the vicinity of Sewell there appear to be considerable areas in which the overburden is less than 15 feet.

There is no water transportation within suitable distance from Sewell, but excellent railroad service is available. Possibly Mantua Creek could be utilized below West Landing for the marl beds within a mile south of Mantua.

Marl of suitable quality is present in sufficient quantity near Sewell to justify large-scale operations and can be worked in open pits by steam shovels or other types of excavators. Water is not so near the surface in Sewell as in some of the other localities tested but would be encountered in handling the green and chocolate-colored beds.

The analyses show that the green marl contains about 1.5 per cent more potash than the bank or chocolate marls but that all the beds may probably be profitably worked by any extraction process applicable to the green marl.

BLACKWOOD.

Years ago the marl was dug and was well exposed near Blackwood. According to Cook,[19]

> At Blackwood town the whole bed ("Middle marl") can be seen by going upstream from Good Intent toward the southeast. David C. Marshall's pits * * * are good examples of the bed, having on top 6 to 12 feet red or gray marl, 7 feet pale-green marl, and from 18 to 20 feet of green marl, and then chocolate marl.

These pits or pits in their vicinity were visited in 1917 by Dr. Kümmel, who observed the following section:

Section of marl beds in pits near Blackwood (locality 48).

	Feet.
Yellow sand and gravel	13–14
Brownish and clayey sand; weathered marl (?)	1
Marl about half quartz and half glauconite	15
Bottom of banks.	
	30

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[19] Cook, G. H., Geology of New Jersey, p. 272, 1868.

The pits in this vicinity are now largely filled in and swampy. In 1918 the writer, with Dr. Kümmel, visited a locality about a quarter of a mile farther up the creek. Here, beneath 15 to 20 feet of Pleistocene sand and gravel, about 4 or 5 feet of lime sand overlies the greensand marl, about 5 feet above the level of the swamp. The shell bed is absent. According to data at the office of the State geologist good exposures of black greensand marl, representing 10 feet of the Hornerstown, occur at locality 49, about 1 mile northwest of Good Intent, beside the road.

The marl is exposed in the fields in the valley between Blackwood and Blenheim, close to the railroad. This might be a suitable place for commercial development, but the full thickness of the marl is probably not present. That the marl is present in considerable thickness at Blackwood is shown by the record of two wells sunk about 2,000 feet apart for F. Pine and H. Runkel. The localities of these wells are not given, but their records are very similar, except that the Pine well starts at a somewhat lower elevation and is a little deeper.[20] Its record, as furnished by M. W. Twitchell, is as follows:

Record of well of F. Pine at Blackwood.

[Elevation, 50 feet. F. E. McCann, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Sand	6	6	Pleistocene.
Red, heavy, stony gravel	10	16	
Gray marl	7	23	Hornerstown and Navesink.
Blue marl	5	28	
Chocolate-colored marl	32	60	
Pepper-and-salt gray sand	10	70	Mount Laurel and Wenonah.

A well sunk at Greenloch, about seven-eighths of a mile southeast of the Camden County asylum, gives the following record:

Record of well of S. R. Bateman (?), near Greenloch (locality 50).

[Elevation, 45 feet. J. L. North, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Dark-gray sand	22	22	Vincentown. (?)
Greenish marl; shells with *Terebratula harlani* near top	28	50	Hornerstown and Navesink.
Greenish marl	30	80	
Pepper-and-salt sand, about half glauconite	1	81	
Light-yellow sand and small shell fragments	23	104	Mount Laurel.
Coarse sand (⅛ to ¼ inch), shell fragments and *Belemnitella*	4	108	

The Pine well, which does not afford a complete section, shows 44 feet of marl. The Bateman well, which apparently gives a com-

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[20] New Jersey Geol. Survey Ann. Rept. for 1901, p. 88, 1902.

plete section, though the lower shell bed seems to be not well developed, shows 59 feet of marl.

No recent data are available regarding the quality of the marl at Blackwood, but it is probable that other conditions being favorable its quality would justify commercial development.

The lime sand occurs along the stream valleys above Blackwood, as shown on the map. Dr. Kümmel notes a good exposure of it at locality 51, by the road at the pumping station, about half a mile northwest of Greenloch, where it consists of a mass of Bryozoa and other fossils and is covered by a reddish clayey residual soil.

A well at Asyla, half a mile northwest of Greenloch, shows 35 feet of greensand, including the *Terebratula* bed, beneath 5 feet of surface soil that contains occasional fragments of lime-sand rock.[21]

SOMERDALE DISTRICT.

SELECTION OF SITES.

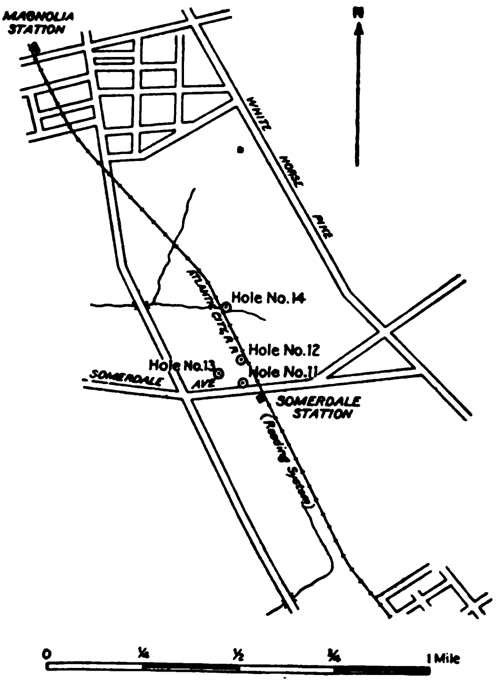

FIGURE 5.—Sketch map of part of the Somerdale district, showing the location of holes 11 to 14.

In the vicinity of Somerdale, in Camden County, the greensand marl occupies a rather broad belt, as shown on the map (Pl. II), and the overburden is apparently not excessive. The Atlantic City Railroad (Reading system) and the Camden & Atlantic Railroad (Pennsylvania system) provide excellent transportation facilities.

A drilling site was selected on the southeast edge of the belt, near Somerdale station, in a corn field belonging to Thomas McMichael, Laurel Springs post office.

HOLES 11 TO 14.

A 2.5-acre tract was again selected and holes 11, 12, and 13 were sunk as indicated in figure 5. A fourth hole, No. 14, was bored about a quarter of a mile northwest of the station, at the culvert on the east side of the track, to explore the so-called red marl, which was reported to be beneficial to crops. The records of these holes follow:

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[21] Woolman, Lewis, Report on artesian wells: New Jersey Geol. Survey Ann. Rept. for 1902, pp. 59-96, 71-72, 1903.

Records of holes in Somerdale district.

Locality 52, hole 11.

[Farm of Thomas McMichael, 50 feet north of Somerdale Avenue and 210 feet west of railroad at Somerdale station. Elevation of surface, about 85 feet. R. K. Bailey, analyst; S. J. Taylor, driller.]

	Thickness.	Depth.	Field No. of sample.	K_2O.	Formation.
	Ft. in.	*Ft. in.*		*Per cent.*	
Topsoil, greenish-yellow clayey sand, becoming more yellowish and containing scattered pebbles.	1 4	1 4	....	....	Quaternary.
Clay, sandy, greenish to grayish drab, with scattered pebbles as large as 1 inch in diameter and grains of weathered glauconite. Toward base deeper color, larger proportion of glauconite, more numerous pebbles.	1 5	2 9	....	....	Do.
Glauconite beds with very stiff olive-colored clay matrix and a few pebbles; red streaks of oxidized material.	3	3	....	....	Do.
Glauconite beds similar to above but with few if any pebbles; red streaks die out at base.	1 2	4 2	M-65	6.94	Hornerstown.
Glauconite beds similar to M-65 but without the weathered iron streaks. At base a pebble 3 inches in diameter.	1 10	6	M-66	7.58	Do.
Glauconite beds, olive-colored, clayey, less stiff and with somewhat mealy texture.	3 3	9 3	M-67	7.52	Do.
Glauconite beds similar to M-67	4 7	13 10	M-68	7.58	Do.
Glauconite beds, a little less clayey, brownish-gray material mingled with olive-green, becomes more brownish at base.	2 9	16 7	M-69	6.74	Navesink.
Glauconite beds similar to above, discarded in clearing casing after driving.	1	17 7	....	....	Do.
Glauconite beds, brownish drab with some intermingling of grayish-green and chocolate-colored streaks, consistency less stiff. A few scattered gravel grains.	4 5	22	M-70	6.67	Do.
Glauconite beds, lighter greenish drab, greenish and chocolate-colored streaks, white films surrounding some of glauconite grains.	5	27	M-71	6.60	Do.
Glauconite beds similar to above but mingled with overlying material in driving pipe and discarded.	1 6	28 6	....	....	Do.
Glauconite beds, greenish drab, rice gravel and quartz sand sufficiently abundant to suggest basal bed of formation.	3	31 6	M-72	5.12	Do.
Glauconite beds becoming more sandy with less clay; glauconite and gravel in diminishing proportion.	5 3	36 9	....	....	Mount Laurel and Wenonah.

Locality 53, hole 12.

[Farm of Thomas McMichael, at Somerdale, 330 feet N. 2½° W. from hole 11. Elevation of surface, about 8 feet. R. K. Bailey, analyst; S. J. Taylor, driller.]

	Thickness.		Depth.		Field No. of sample.	K₂O.	Formation.
	Ft.	*in.*	*Ft.*	*in.*		*Per cent.*	
Top soil about 3 inches, then stiff olive-green glauconitic clay with rootlets worked by plow to depth of about		10		10	....	....	Quaternary.
Glauconite beds, olive-green, stiff, clayey, streaked with red iron-stained clay. Two pebbles noted at depths of 22 and 28 inches but rejected from sample, a few gravel grains included.	2	2	3	0	M-74	5.43	Do.
Glauconite beds, olive-green, stiff, clayey, with a few brownish streaks. A few gravel grains and one pebble noted.	3	3	6	3	M-75	7.32	Hornerstown.
Glauconite beds, yellowish olive-colored, somewhat mealy texture, yellowish sandy streaks, fine yellow powdery clay at base.	3	2	9	5	M-76	7.42	Do.
Glauconite beds, light chocolate-brown with mingling of green in upper 4 inches.	2	5	11	10	M-77	6.44	Navesink
Glauconite beds, drab to grayish green, firm, hard to drill, much clay but considerable percentage of black glauconite.	5		16	10	M-78	6.64	Do.
Glauconite beds, brownish to greenish drab, with irregular streaks of brown and green, somewhat mealy texture, much black glauconite.	5		21	10	M-79	6.57	Do.
Glauconite beds like last but with some grains of quartz and a few gravel grains at base.	3		24	10	M-80	6.12	Do.
Glauconite beds similar to M-79................	1	3	26	1			
Glauconite beds, sandy and hard to drill, a sort of hardpan; considerable quartz mixed with the glauconite; cementing clay chocolate-brown; becomes more sandy downward with abundant grains of rice gravel near base; no shells observed.		3	29	1	M-81	3.44	Do.

Locality 54, hole 13.

[Farm of Thomas McMichael, Somerdale, 330 feet S. 87½° E. from center of line between holes 11 and 12. Elevation of surface, about 89 feet. R. K. Bailey, analyst; S. J. Taylor, driller.]

	Thickness.	Depth.	Field No. of sample.	K₂O.	Formation.
	Ft. in.	*Ft. in.*		*Per cent.*	
Top soil brownish drab, somewhat sandy clay with yellow sandy streaks, grading downward into yellowish olive-colored glauconitic clay.	1 1	1 1	....	....	
Glauconite beds, stiff, yellow to dark olive-colored, grading into light green, with yellow and reddish iron-stained streaks, somewhat micaceous and containing a few small pebbles and grains of gravel.	3	4 1	M-82	3.74	Quaternary. Do.
Glauconite beds, light green, relatively free from yellow oxide of iron, mealy texture, micaceous, considerable fine quartz (in part débris from Kirkwood formation?).	1 5	5 6	M-83	3.51	Do.
Sandy clay bed with scattered quartz pebbles becoming numerous downward, pebbles as large as 2 inches in diameter, bed very compact.	1	6 6	....	....	Do.
Glauconite beds, deep olive-colored, somewhat mealy texture, some yellow iron-stained streaks.	4 6	11	M-84	7.45	Hornerstown.
Glauconite beds, deep green or olive-colored, clayey but with somewhat mealy texture, numerous streaks of yellow iron-stained clay, scattered pebbles ¼ inch in diameter and a few gravel grains.	3 4	14 4	M-85	7.66	Do.
Glauconite beds, brown, stiff, clayey, with streaks of green material like preceding.	2 4	16 8	M-86	6.15	Navesink.
Glauconite beds like M-86, of which 8 inches was inadvertently included; sample represents total thickness of 4 feet 6 inches.	3 10	20 6	M-87	6.63	Do.
Glauconite beds similar to preceding but with less of intermingled green material.	6 6	27	M-88	6.55	Do.
Glauconite beds, brown with green streaks, stiff, clayey; grayish-white coatings on some of the grains.	3 6	30 6	M-89	6.70	Do.
Glauconite beds, brownish drab, clayey, with gravel grains as large as ¼ inch in diameter and grains of quartz; bed hard and compact.	3 6	34	M-90	4.65	Do.
Glauconite beds, blackish brown, clayey, with considerable quartz and grains of rice gravel, one pebble ¼ inch in diameter noted.	4	34 4	....	....	Do.
Sand, drab, clayey, with rice gravel and some glauconite.	2 8	37	....	....	Do.
Sand, somewhat clayey, containing gravel grains, brown clay at base. Hole dry at this depth.	3 6	40 6	....	....	Mount Laurel and Wenonah.

Locality 55, hole 14.

[Farm of Thomas McMichael, Somerdale, at culvert about one-fourth of a mile northwest of Somerdale station, east of track and north of creek. R. K. Bailey, analyst; S. J. Taylor, driller.]

	Thickness.	Depth.	Field No. of sample.	K₂O.	Formation.
	Ft. in.	*Ft. in.*		*Per cent.*	
Clay, green, glauconitic, somewhat sandy, with scattered pebbles; irregular red iron-stained streaks.	2 10	2 10	....	....	Quaternary.
Deposit locally called "red marl." Clay, red with iron oxide, glauconitic; contains gravel and pebbles as large as 1 inch in diameter; includes a 2-inch layer of stiff green glauconitic clay.	8	3 6	M-91	4.22	Do.
Clay, "red marl," red with oxide of iron, glauconitic; grains of quartz, a few small pebbles and gravel grains suggesting rice gravel.	1 11	5 5	M-92	2.96	Do.
Sand, quartz, with some glauconite and much iron oxide.	2 5	7 10	....	....	Mount Laurel and Wenonah.
Sand, white quartz, succeeded by reddish sand with iron oxide, water bearing.	1 2	9	....	....	

For comparison with other localities the data furnished by holes 11 to 13 are summarized below.

Thickness and quality of greensand beds at holes 11 to 13, Somerdale.

Hole.	Bed.	Sample No.	Thickness represented.	K_2O.	Thickness of bed.	Average content of K_2O.[a]
			Ft. in.	*Per cent.*	*Ft. in.*	*Per cent.*
11	Overburden	....	....	....	3	....
	Green marl	M-65	1 2	6.94	10 10	7.49
		M-66	1 10	7.58		
		M-67	3 3	7.52		
		M-68	4 7	7.58		
	Chocolate marl	M-69	2 9	6.74	17 8	[b] 6.33
		....	1	....		
		M-70	4 5	6.67		
		M-71	5	6.60		
		....	1 6	....		
		M-72	3	5.12		
12	Overburden	....	....	....	10	....
	Green marl	M-74	2 2	5.43	8 7	6.88
		M-75	3 3	7.32		
		M-76	3 2	7.42		
	Chocolate marl	M-77	2 5	6.44	16 8	6.46
		M-78	5	6.64		
		M-79	5	6.57		
		M-80	4 3	6.12		
13	Overburden	....	....	....	1 1	....
		M-82	3	3.74	4 5	3.67
		M-83	1 5	3.51		
	Green marl	M-84	4 6	7.45	7 10	7.54
		M-85	3 4	7.66		
	Chocolate marl	M-86	2 4	6.15	19 8	6.21
		M-87	3 10	6.63		
		M-88	6 6	6.55		
		M-89	3 6	6.70		
		M-90	3 6	4.65		
	Average:					
	Overburden	....	....	....	3 1	....
	Green marl	....	....	....	9 1	[c] 7.35
	Chocolate marl	....	....	....	18	[c] 6.32
					27 1	[d] 6.66

[a] Average for bed weighted according to the thicknesses represented by the respective samples.
[b] Average for 15 feet 2 inches but assumed to be approximate for entire bed of 17 feet 8 inches.
[c] Average for the bed in 2.5-acre tract weighted according to its thickness at the respective holes.
[d] Average of entire thickness of marl in the 2.5-acre tract.

As shown in the above table, the maximum thickness of the overburden in the 2.5-acre tract is 5 feet 6 inches, and the average is 3 feet 5 inch. At hole 13 the overburden consists in part of reworked marl and carries significant amounts of potash, though perhaps not enough to be considered commercially.

The green marl in the same tract has a maximum thickness of 10 feet 10 inches, averages about 9 feet, and carries 7.54 per cent of potash (K_2O). The chocolate marl has a maximum thickness of 19 feet 8 inches, averages 18 feet, and contains 6.21 per cent of potash. The entire marl bed averages 27 feet in thickness and carries 6.66 per cent of potash.

At hole 14 the so-called red marl consists of reworked glauconitic material, oxidized, and mingled with gravel but containing a maximum of 4.22 per cent of potash for the samples analyzed. The

material appears to be a local deposit of Quaternary age which contains too little potash to be of commercial interest.

WELL DATA.

A number of wells sunk within a radius of 2 or 3 miles of Somerdale throw additional light on the thickness and character of the overburden and the thickness of the marl in the Somerdale district. At Magnolia a well drilled near the station [22] showed 4 feet of overburden consisting of yellow clay and sand succeeded by 32 feet of "blue" marl underlain by water-bearing sands and other strata to the depth of 91 feet. A well drilled for Walter Hunt [23] about three-quarters of a mile northwest of Kirkwood station (locality 56?), shows 50 feet of greensand marl beneath 44 feet of yellow quicksand, and a second well,[24] described as 1 mile south-southeast of the well just cited, shows 30 feet of "black mud" (greensand?) and 12 feet of green marl beneath 50 feet of yellow quicksand.

The well at the Stratford House, nearly midway between Kirkwood station and Stratford station and on nearly the highest ground, furnishes the following record:[25]

Record of well at Stratford House, near Kirkwood (locality 57).

[Elevation, 100 feet. Water rises within 51 feet of surface.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Dug well	33	33	[Tertiary?]
Fine yellow sand	8	41	
Coarse yellow sand	2	43	
Yellowish loamy gravel	3	46	
Yellowish clayey sand	2	48	
Green marly clay, very hard	7	55	[Hornerstown and Navesink.]
Black marly sand	3	58	
Green marly clay, very hard	13	71	
Black marly sand with water	5	76	
Green clayey marl, very sticky	4	80	
Limerock (?), very hard	2	82	
Brown marly clay, soft and sticky	4	86	
Black sand and gravel with water	3	89	
Hard stony conglomerate	2	91	
Light-green marly clay	2	93	
Sand in layers, softer and harder	7	100	[Mount Laurel and Wenonah.]

If the above record is properly interpreted there is 45 feet of marl beneath 48 feet of overburden.

At Laurel Springs a well drilled southwest of the railroad, near the millpond, for Joseph Eldridge [26] shows the following record:

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[22] New Jersey Geol. Survey Ann. Rept. for 1894, p. 197, 1895.

[23] Idem for 1901, p. 86, 1902.

[24] Idem, p. 87.

[25] Idem for 1897, pp. 255-256, 1898.

[26] Idem for 1901, p. 88, 1902.

Record of well of Joseph Eldridge, near Laurel Springs (locality 58?).

[Elevation, 60 feet. F. E. McCann, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Loamy yellow gravel; suitable for road making	18	18	Quaternary.
Chrome or orange-yellow quicksand	22	40	Kirkwood(?)
Green marl, blue marl, chocolate marl	40	80	Hornerstown and Navesink.
Dark-colored hard sand	15	95	Mount Laurel and Wenonah.
Shell bed	7	102	
Hard stone	1	103	
White sand, water bearing.			

The position of the base of the Navesink is not clear from the above section, but there seems to be at least 40 feet of marl beneath 40 feet of overburden at this locality.

OTHER DATA.

From an old marl pit southwest of Laurel Springs, where the greensand was 10 to 12 feet thick and was overlain by 20 feet of overburden, W. C. Phalen collected a sample which was analyzed in the laboratory of the United States Geological Survey and found to contain 6.40 per cent of potash.[27]

A large marl pit at locality 59, on the west side of the railroad track, about 0.6 mile N. 20° W. of Kirkwood station, was visited by Dr. Kümmel, who observed the following section at the north end of the pit near the railroad:

Section at marl pit about 0.6 mile N. 20° W. of Kirkwood station (locality 59).

[Elevation, about 58 feet.]

	Thickness.	Formation.
	Feet.	
A. Greenish marly sandy clay, very tough	2-3	Pleistocene.
B. Coarse greenish marly sand and fine gravel	3-4	Do.
C. Marl exposed about 3 feet above floor of pit	3	Hornerstown.
	10	

There are no data about the former depth of the pit.

In 1918 a pit was opened in ground purchased by the Coplay Cement Co., of Coplay, Pa., at locality 60, about 0.3 mile due south of Osage station. A few carloads of greensand dug in this pit were shipped from Ashland. The pit was largely filled with water in

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[27] Ashley, G. H., Notes on the greensand deposits of the eastern United States: U. S. Geol. Survey Bull. 660, pp. 40, 47, 1918.

March, 1919. About 1.5 feet of greensand, corresponding with the green marl of holes 11 to 13, was exposed beneath an overburden of about 4 feet of sand, including a 6-inch gravel bed just above the marl. A sample representing 1 foot of fresh material, analyzed in the laboratories of the Geological Survey, showed a total potash content of 7.17 per cent.

LIME SAND.

As shown on the map, the lime-sand phase of the Vincentown formation is exposed in branches of Timber Creek, near Laurel Springs. Beds of indurated lime sand full of Bryozoa may be seen at locality 61, in the bed of the brook, below the bridge 1½ miles west of Clementon. Some material taken for experimental purposes from this locality is reported to have contained as much as 80 per cent of carbonate of lime. Above Laurel Springs the lime sand occurs in close proximity to the railroad.

ESTIMATES OF TONNAGE AND VALUE.

As stated on page 64, the average thickness of the marl bed in the 2.5-acre tract at Somerdale is 27 feet, and its average potash content is 6.66 per cent. On the assumption, as in previous estimates, of 28 per cent of voids and a weight of 133 pounds per cubic foot, the total potash in an acre of the 2.5-acre tract would amount approximately to $\frac{43{,}560\times 27\times 133\times 0.0666}{2{,}000}=5{,}200$ tons. In the 2.5-acre tract the total potash would be about 13,000 tons.

With an 80 per cent recovery and a price of $2.50 per unit of 20 pounds (March, 1920) the potash in a ton of greensand would be worth $13.32 and in an acre of the specified tract it would be worth $1,040,000. At the more probable price of $1.50 per unit the same quantities of potash would be worth $7.99 and $624,000 respectively. As in the previous estimates the values given for the potash are hypothetical, being dependent on the extraction of the potash by processes whose success has not yet been commercially demonstrated.

UTILIZATION OF THE DEPOSITS.

The 2.5-acre tract at Somerdale station is part of a larger area of suitable size and of sufficient potash content to justify commercial exploitation. No water transportation is available, but the district is served by two railroads and lies only 9 or 10 miles from Delaware River at Camden.

At holes 11 to 13 the water level was not reached at a depth of 40 feet 6 inches, and the marl was dryer than at any of the other holes

bored. Absence of water would doubtless be an advantage in handling and shipping.

Northwestward from these holes the thickness of the marl may be expected to diminish to zero along the general northwest boundary of the belt indicated on the map (Pl. II). Along the southeast boundary, as shown by the well records cited, a thickness of 40 to 45 feet may be expected, but the overburden also is probably thicker.

WINSLOW.

A well at Winslow, near Hammonton, in Camden County, shows the increase in depth of the marl beds in the direction of the dip. In a distance of about 13 miles the top (?) of the Hornerstown marl has descended about 300 feet. This well was sunk about 1853 and is thought by Twitchell to be the first deep well in New Jersey. Its record has been repeated in somewhat varying form in reports of the New Jersey Survey from 1868 (Cook) to 1890. Its record, as worked out by Knapp,[38] follows:

Record of well at Winslow.

	Thickness.	Depth.
	Feet.	*Feet.*
Surface earth dug away	5	5
Blue and black clay	15	20
Glass sand described as quicksand	95	115
Miocene clay described as hard black clay	35	150
Miocene sand described as quicksand	107	257
Brown clay described as hard black clay	43	300
Greensand marl shells, etc	20	320
Pure greensand, no fossils; "Water rose from the bottom of the greensand" [a]	15	335

[a] Cook, G. H., Geology of New Jersey, p. 291, 1868.

MARLTON DISTRICT.

SELECTION OF AREA.

In the vicinity of Marlton the area occupied by the combined Hornerstown and Navesink marls expands to a broad belt about 2 miles wide. The greensand may be recognized in the roads and the plowed fields at many places. A number of marl pits were opened in the early days, and the marl was much used. More recently the Atlantic Potash Co. has opened pits, described below, along the railroad, about 1.1 miles east of Marlton, for commercial exploitation of the marl and the extraction of the potash. About 1 mile southeast of Marlton the Vincentown sand emerges from Tertiary cover, though it is still concealed to a greater or less degree by Quaternary deposits.

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[38] Knapp, G. N., data on file at the office of the State geologist, Trenton.

The field of Alphonso Fusco, at Elmwood Road station, about 1.8 miles east of Marlton, was selected for exploration because, so far as could be told from the map and the general appearance of the country, it lies near the contact of Vincentown sand and Hornerstown marl, so that a full thickness of greensand marl might be expected. The overburden, too, was thought to be relatively thin.

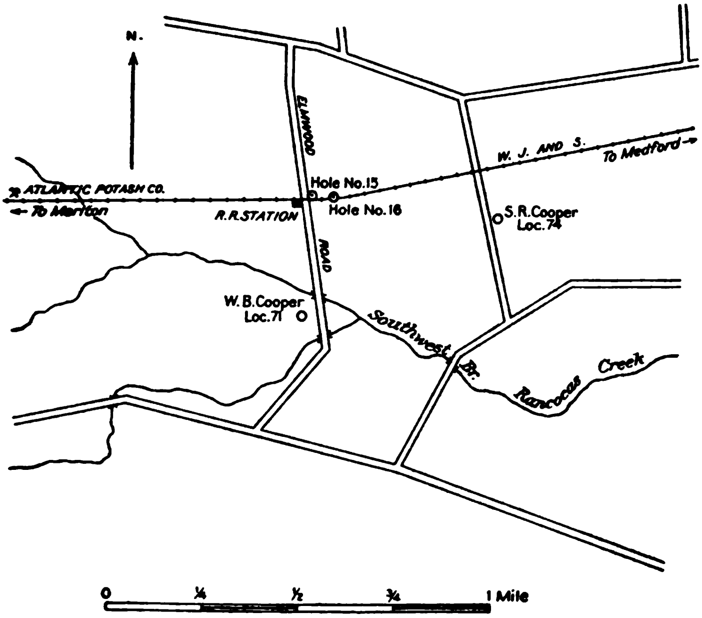

FIGURE 6.—Sketch map of part of the Marlton district, showing the location of holes 15 and 16.

HOLES 15 AND 16.

A 2.5-acre tract was laid out east of the road and north of the railroad, and two holes were sunk 330 feet apart, as indicated in figure 6. A third hole was planned, but the contract for drilling expired before it could be started. The records of holes 15 and 16 follow.

Records of holes in Marlton district.

Locality 62, hole 15.

[Farm of Alphonso Fusco, Elmwood Road, 65 feet N. 63° E. from center of railroad crossing just east station. Elevation of surface, about 65 feet. R. K. Bailey, analyst; S. J. Taylor, driller.]

	Thickness.	Depth.	Field No. of sample.	K_2O.	Formation.
	Ft. in.	*Ft. in.*		*Per cent.*	
Soil, rather sandy, with some clay	6	6	....	....	Quaternary.
Sand, clayey, somewhat glauconitic, yellowish drab, becoming greenish yellow.	2 6	3	....	....	Do.
Sand, clayey, glauconitic, with some mica and a few pebbles (one angular granitic fragment ¾ inch in diameter noted), yellowish green, water bearing, hard at base.	8 6	11 6	....	....	Do.
Sand like last but with more gravel and pebbles; one pebble 2 inches in diameter; material hard and compact.	2	13 6	....	....	Do.
Glauconite beds, black, with considerable quartz, contain some lumps of yellow sandy clay and scattered pebbles; one subangular quartzite pebble 1½ inches in diameter; material runs like quicksand.	3 6	17	....	....	Do.
Glauconite beds, with fine quartz sand and dark greenish-drab clay; runs; some layers apparently more firm and form lumps with greasy feel; some layers dry, but sand as whole is water bearing.	5	22	M-98	4.82	Vincentown.
Glauconite beds, coarse grains, smaller proportion of clay, shell fragments, one or two casts poorly preserved, occasional nodules of hard gray and brown clay with included grains of glauconite, concretions of marcasite.	6 2	28 2	M-99	6.68	Hornerstown.
Glauconite beds similar to last but with more greenish tint, water bearing; material appears to be compact but when loosened is a runny glauconitic sand with fine grains and comparatively little clay. Poorly preserved coralline fossils and concretions.	5	33 2	M-100	7.33	Do.
Glauconite beds, greenish black, similar to M-100 but glauconite grains slightly coarser and there is somewhat more green clay; runs easily.	1 10	35	M-101	7.61	Do.
Glauconite beds like above, but shells are scattered through the material.	3 6	38 6			
Glauconite beds like M-100-101; material represents basal part of dark-green marl, runs easily.	1 11	40 5	M-102	7.55	Do.
Glauconite beds, chocolate-colored marl, glauconite mingled with much brown clay and tiny flakes of mica.	4 10	45 3	M-103	6.30	Navesink.
Glauconite beds, brownish black; clayey beds fairly firm.	3 6	48 9	M-104	6.38	Do.
Glauconite beds similar to last but with scattered shells.	1 6	50 3			
Glauconite beds similar to M-104. Shells scattered through brownish-black glauconitic clay.	4 11	55 2	M-105	6.45	Do.
Glauconite beds similar to M-105; material dries to a gray color.	4 10	60	M-106	6.28	Do.
Glauconite beds similar to above; contain a few grains like rice gravel and some shell fragments.	4 4	64 4	M-107	6.60	Do.
Glauconite beds, brownish black; glauconite and clay continue abundant but gravel grains and shell fragments become more numerous, one fragment of *Belemnitella* noted at 67 feet. At base gravel and shell fragments become abundant. *Belemnitella* fragments numerous.	5 4	69 8	M-108	5.12	Do.

Locality 63, hole 16.

[Farm of Alphonso Fusco, Elmwood Road, 330 feet S. 82° E. from hole 15. Elevation of surface, about 61 feet. R. K. Bailey, analyst; S. J. Taylor, driller.]

	Thickness.		Depth.		Field No. of sample.	K_2O.	Formation.
	Ft.	*in.*	*Ft.*	*in.*		*Per cent.*	
Soil, brown clayey sand with some humus......	1		1		....	....	Quaternary.
Sand, clayey, yellow to yellowish-green........	1		2		....	....	Do.
Clay, glauconitic and sandy, green with yellow streaks of iron-stained clay. Lower 8 inches sandy, water bearing, considerable quartz and one pebble noted at base.	4		6		M-109	3.10	Do.
Clay, sandy, glanconitic, yellowish green.......	1	8	7	8	....	....	Do.
Sand, clayey, dark grayish green; sand is principally quartz but includes considerable glauconite, almost a quicksand. At 11 feet material more firm, hard to drill. Proportion of glauconite increases with depth and quartz becomes coarser, gravel grains scattered through but disappear near base. Clay becomes greenish toward base.	8	4	16		....	....	Vincentown (?).
Clay, glauconitic and sandy, greenish gray to black. Probably basal portion of Vincentown formation.	3		19		M-110	5.68	Do.
Glauconite beds, brownish gray to grayish-black, shell bed with casts of *Terebratula* and other forms, nodules of marcasite, scattered rounded grains of gravel as large as ½ inch in diameter, bed hard and compact.	3		22		M-111	6.58	Hornerstown.
Glauconite beds, soft and runny with comparatively little clay, but slightly micaceous, green streaks mingled with the brown give general dark grayish color.	2		24				
Glauconite beds, brown and green clayey material, compact, fossil corals more or less replaced by glauconitic clay.	3	8	27	8	M-112	6.86	
Glauconite beds, stiff clay layer in upper 2 feet, lower part soft and runny, distinct dark greenish color; a few grains of gravel, one pebble ½ inch in diameter, and a few shell fragments noted; about 1 foot above base clay becomes a lighter green.	5	4	33		M-113	7.11	
Glauconite beds similar to last, brown, clayey..	3		36		M-114	7.13	
Glauconite beds, greenish, quartzose, gravelly, water bearing, casts of shells, small flakes of mica.		7	36	7			
Glauconite beds, brownish, clayey..............		11	37	6			Navesink.
Glauconite beds, brown, clayey, probably correspond with chocolate marl of Sewell; carry considerable glauconite; one fragment of shark tooth noted at about 40 feet.	10	1	47	7	M-115	6.84	
Glauconite beds similar to last.................	10	5	58		M-116	6.36	
Glauconite beds, brown, clayey, include small shell fragments and a few grains of gravel.	3	4	61	4	M-117	6.58	
Glauconite beds, shell fragments increase in number, rice gravel and fragments of *Belemnitella*, less clay, abundant glauconite, considerable quartz, water bearing.	3	2	64	6	M-118	5.62	

The data furnished by holes 15 and 16 are summarized below:

Thickness and quality of greensand beds at holes 15 and 16, Elmwood Road.

Hole.	Bed.	Sample No.	Thickness represented.	K_2O.	Thickness of bed.	Average content of K_2O.[a]
			Ft. in.	*Per cent.*	*Ft. in.*	*Per cent.*
15	Overburden	....	....	....	17	....
	Black marl	M-98	5	4.82	11 2	5.85
		M-99	6 2	6.68		
	Green marl	M-100	5	7.33	12 3	7.49
		M-101	5 4	7.61		
		M-102	1 11	7.55		
	Chocolate marl	M-103	4 10	6.30	29 3	6.16
		M-104	5	6.38		
		M-105	4 11	6.45		
		M-106	4 10	6.28		
		M-107	4 4	6.60		
		M-108	5 4	5.12		
16	Overburden	....	....	....	16	....
	Black marl	M-110	3	5.68	8	6.24
		M-111	5	6.58		
	Green marl	M-112	3 8	6.86	13 6	[b] 7.05
		M-113	5 4	7.11		
		M-114	4 6	7.13		
	Chocolate marl	M-115	10 1	6.84	27	6.48
		M-116	10 5	6.36		
		M-117	3 4	6.58		
		M-118	3 2	5.62		
	Average:					
	Overburden	....	....	....	16 6	....
	Black marl	....	....	....	9 7	[c] 6.01
	Green marl	....	....	....	12 11	[c] 7.26
	Chocolate marl	....	....	....	28 2	[c] 6.32
					50 8	[d] 6.50

[a] Average for bed weighted according to the thicknesses represented by the respective samples.
[b] Includes 11 inches of chocolate marl.
[c] Average for the bed in the 2.5-acre tract weighted according to its thickness at the respective holes.
[d] Average of entire thickness of marl in the 2.5-acre tract.

As shown in the above table, the maximum thickness of the overburden in the 2.5-acre tract, as inferred from the two holes, is 17 feet and the average is 16.5 feet. The land rises slightly toward the north side of the tract, so that 17 or 17.5 feet would perhaps be a fairer average for the overburden.

The presence of the *Terebratula*-bearing bed at hole 16 fixes definitely the position of the top of the Hornerstown at 19 feet at that place; the corresponding bed, not so well marked, occurs at 22 feet at hole 15, where the surface elevation is 4 feet higher (65 feet).

Above the top of the Hornerstown is a bed 5 feet thick at hole 15 and 3 feet thick at hole 16, consisting largely of fine quartz sand and glauconite with more or less clay. This bed is presumably the basal part of the Vincentown sand but may represent reworked material of Pleistocene age. It contains sufficient glauconite to warrant its inclusion with the underlying marl beds, and it is here classed with the black marl.

The black marl has a maximum of 11 feet 2 inches, averages 9 feet 7 inches, and contains 6.01 per cent of potash (K_2O). The green

marl has a maximum thickness of 13 feet 6 incnes, averages 12 feet 11 inches, and contains 7.26 per cent of potash. The chocolate marl has a maximum thickness of 29 feet 3 inches, averages 28 feet 2 inches, and contains 6.32 per cent of potash. The entire bed averages 50 feet 8 inches or, for purposes of computation, say 50 feet in thickness and contains 6.50 per cent of potash.

WELL DATA.

Numerous wells sunk within a radius of 2 or 3 miles of Marlton serve to check the thickness and continuity of the marl and show the general thickness of the overburden in the district. At locality 64, which is on relatively high ground midway between Marlton and Ashland and southeast of the marl belt as mapped, there is 50 feet of greensand beneath 81 feet of overburden, as shown in the following record:[29]

Record of well of S. C. Gardiner, about 2.5 miles southwest of Marlton, on road to Ashland (locality 64).

[Elevation, 147 feet. W. C. Barr, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Dug well	40	40	[Quaternary?]
Yellow quicksand	35	75	
Gravel and coarse sand mixed	6	81	
Green marl	20	101	[Hornerstown and Navesink.]
Chocolate marl	30	131	
Sand with water	6	137	[Mount Laurel and Wenonah.]

Three wells at Marlton show considerable thicknesses of marl, but they also show a rather thick overburden.

Record of well of H. B. Dunphey, at Marlton (locality 65).[a]

[Elevation, 105 feet. W. C. Barr, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Top soil, yellow loam and gravel	18	18	Pleistocene.
Black marl	14	32	[Hornerstown and Navesink.]
Green marl	9	41	
Chocolate marl, with white shell, probably *Gryphaea*	29	70	
Gray sand with irony water	12	82	[Mount Laurel and Wenonah.]
Black sand	40	122	
Black clay	72	194	[Marshalltown.]
Fine white sand with good water	6	200	[Englishtown.]

[a] New Jersey Geol. Survey Ann. Rept. for 1895, p. 69, 1896.

If the black marl beneath the gravel is considered part of the Hornerstown there is a thickness of 52 feet of marl beneath an over-

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[29] New Jersey Geol. Survey Ann. Rept. for 1896, p. 143, 1897.

burden of 18 feet. The records of the well at locality 66 and of hole 16 suggest that this black marl may perhaps more properly be assigned to the Kirkwood or the Vincentown.

Record of well at waterworks, Marlton (locality 66).[a]

[About 0.6 mile south of railroad station. Elevation, 115 feet(?). A. G. Dunphey, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Soil	9	9	[Quaternary?]
Yellow gravel	5	14	
Yellow quicksand	15	29	[Kirkwood?]
Black mud	20	49	
Marl	25	74	[Hornerstown and Navesink.]
Brown mud (chocolate marl?)	19	93	
Mud and shell	3	96	
Gray sand with abundance of water, somewhat irony	10	106	[Mount Laurel and Wenonah.]
White sand	1	107	
Black sand	1	108	
Whitish or gray sand	17	125	
Black sandy mud	(30)	(155)?	
Black clay at	(30)	(185)?	[Marshalltown?]
Black muddy sand	(11)	(196)?	
Sandy marl	(12)	(208)?	
Light-colored sand	(4)	(212)?	[Englishtown?]
Yellowish-white sand with satisfactory water.			

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[a] New Jersey Geol. Survey Ann. Rept. for 1897, pp. 259-260, 1898.

Here there is 47 feet of marl beneath 49 feet of overburden.

The writer is indebted to M. W. Twitchell for the following record and interpretation of the neighboring well of T. R. Wills:

Record of well of T. R. Wills, near Marlton (locality 67).

[Five-eighths of a mile south of Marlton. Elevation, 100 feet. A. G. Dunphey, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Soil and yellow loam	12	12	Kirkwood.
Gravel and greenish-yellow sand	3	15	
Yellowish sand with some greensand grains	7	22	
Dark or black clay	10	32	
Sand, mixture of greensand and white quartz grains	4	36	
Greensand marl, somewhat clayey	14	50	Hornerstown and Navesink.
Pure greensand marl, called powder-grain marl	10	60	
Chocolate marl	8	68	
Chocolate marl, darker shade	14	82	
Mixture of greensand and quartz sand, with some thin crusts of irony conglomerate; contains *Gryphaeostrea vomer* and a more ponderous *Gryphaea* or oyster, too fragmentary for specific identification, also the mineral vivianite, replacing the lime of some of the shells.	5	87	Mount Laurel and Wenonah.
Medium-coarse sand, slightly greenish yellow	9	96	
Medium-coarse sand, greenish yellow but darker	2	98	
Finer sand, similar in color, but containing numerous pale yellowish-green casts of Foraminifera.	20	118	
Sand, slightly clayey	12	130	
Sand, mainly quartz grains	13	143	
Black sandy clay	52	195	Englishtown.
Hard crust, consisting of sand conglomerate, shells, and other fossils. In this stratum were found the cusp of a tooth of *Thoracosaurus neocesariensis* Leidy, a gavial related to the crocodile, and also the molluscan genera *Cardium*, *Gryphaea*, and *Pecten*.	1	196	
Clean, clear yellowish quartzose sand, without greensand grains, *water bearing*.	3	199	
Sandy clay, with greensand.			

At this locality the top of the Hornerstown is not present, but there is 46 feet of greensand beneath 36 feet of overburden, consisting of Kirkwood sand.

A well sunk for Joseph Evans, about 1.5 miles southeast of Marlton, furnishes the following record:

Record of well of Joseph Evans, 1.5 miles southeast of Marlton (locality 68).[a]

[Elevation, 129 feet.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Sand	20	20	[Kirkwood ?]
Black loam or marl	50	70	
Sand	14	84	[Vincentown ?]
Crust	9	93	
Green marl	27	120	[Hornerstown and Navesink ?]
Sand	27	147	
Crust of oyster and other shells	2	149	
White sand with water	6	155	[Mount Laurel-Wenonah.]

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[a] New Jersey Geol. Survey Ann. Rept. for 1894, pp. 214-215, 1895.

If the writer's interpretation of the above record is correct there is 54 feet of greensand marl beneath 93 feet of overburden. The "crust" at a depth of 84 feet is thought to be the more massive lime-sand phase of the Vincentown, but it may represent the shell bed at the top of the Hornerstown. The shell bed at a depth of 147 feet is probably the base of the Navesink.

Record of well of J. W. Barr, about 2 miles east of Marlton (locality 69).[a]

[Elevation, 70 feet.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Soil and green clay	10	10	[Quaternary.]
Coarse sand and gravel	10	20	
Black and green marl	14	34	[Hornerstown and Navesink.]
Chocolate marl	30	64	
Shell crust with *Belemnitella*	4	68	
Sand, water bearing	....	....	[Mount Laurel and Wenonah].

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[a] New Jersey Geol. Survey Ann. Rept. for 1894, p. 209, 1895.

The upper shell bed is not present at this locality, but beneath 20 feet of clay, sand, and gravel there is 48 feet of greensand marl, including the lower shell bed.

The records of a number of other wells in the vicinity of Marlton, so far as they relate to the marl and its overburden, are summarized in the following table.

Thickness of overburden and of marl at several wells near Marlton.

Locality.	Reference (New Jersey Geol. Survey Ann. Rept.).	Owner.	Overburden.	Marl.	Driller.
			Feet.	*Feet.*	
70	1894, p. 215	Jacob L. Evens	40	58?	
70a?	1899, p. 69	do.	7	51	A. G. Dunphey.
....	1894, p. 206	Samuel Lippincott	26	54	W. C. Barr.
....	1894, p. 213	William J. Evans	50	67	Do.
....	1894, p. 210	Josiah Ballenger	30?	40	Stotthoff Bros.
71	(a)	W. B. Cooper	20±	50	
72?	1894, p. 211	Benjamin Cooper	31	35?	J. W. Barr.
73	1897, pp. 260-261	T. C. Hammitt	85	42	A. G. Dunphey.
....	1894, p. 213	B. S. Lippincott	50	45	W. C. Barr.
....	1894, p. 214	Levi T. Ballenger	20+	56?	Do.
....	1894, p. 216	A. W. Lofland	58	37	Do.
74	(a)	Samuel R. Cooper	30	50	
			37	49	

[a] Personal communication.

Definite locations for a number of these wells are not available, but they all lie within 3 miles of Marlton and mostly to the east or southeast. They are near the southeast boundary of the marl belt and show an average thickness of about 49 feet of marl beneath about 37 feet of overburden, which, at several of the wells, consists in part of Vincentown and Kirkwood sands.

OTHER DATA.

Some of the marl exposed in plowed fields and along roads near Marlton is reworked material of Pleistocene age that might readily be mistaken for marl in place. For example, at locality 75, between Marlton and Evesboro, Dr. Kümmel noted in 1915 a good exposure of reworked marl 2 feet thick resting on a bed of yellow iron-stained gravel also about 2 feet thick. In the old marl pits in that vicinity the only exposures at present show reworked marly clay with pockets of gravel. The real marl occurs below the floor of the pits at an elevation of about 90 feet and beneath the gravel.

The pits of George T. Middleton, at locality 76, about 1.1 miles N. 78° E. from Marlton station, are entered from the Evesboro-Medford road. According to information furnished to Dr. Kümmel in 1917 these pits have not been dug recently, but the marl lies near the surface with only 2 or 3 feet of overburden and no shell bed. The marl was formerly dug to a depth of 12 feet, where water interfered with digging, but the marl was said to be much thicker and to contain more than 7 per cent of potash.

ATLANTIC POTASH CO.'S PIT.

The pit of the Atlantic Potash Co. lies about 1.1 miles due east of Marlton, at locality 77, just north of the railroad. At the time of the writer's visits, in October, 1918, and January and March, 1919, the

A. DREDGE, PIT, AND STOCK PILE OF ATLANTIC POTASH CORPORATION ABOUT 1.1 MILES EAST OF MARLTON, BURLINGTON COUNTY, N. J.

Note abundance of water in pit.

B. RECENT DIGGING AT NORTHWEST CORNER OF WEST JERSEY MARL & TRANSPORTATION CO.'S MARL PIT NEAR SEWELL, GLOUCESTER COUNTY, N. J.

pit was filled with water. In September, 1917, fresh surfaces were exposed and Dr. Kümmel measured the following section:

Section at pit of Atlantic Potash Co., 1.1 miles east of Marlton (locality 77).

	Feet.
Sandy clay and gravel	3-5
Yellow bed, *Gryphaea* shells, iron stained and more or less decomposed	2-2½
White unaltered shells, 80 per cent *Gryphaea*, some *Terebratula harlani;* upper contact very sharp and approximately horizontal.	½-1
Dark greenish-black marl, exposed	6-7
	15½

It was stated that 40 feet of marl had been dug here without reaching bottom, and that about 13 feet from the top the marl became a little more greenish.

The condition of the pit in March, 1919, is shown in Plate VIII, A. Determinations of the weight of the marl per cubic foot were made on relatively fresh run of mine material, as described on pages 19–20. A sample of this material analyzed at the Survey laboratories contained 7.63 per cent of potash (K_2O).

LIME SAND.

The lime sand does not come to the surface in the Marlton district, but it is penetrated in a number of wells in the eastern and southeastern parts of the district. The map shows its probable distribution northeastward from a place about 1 mile southeast of Marlton, where it emerges from beneath Tertiary beds but is still concealed by Quaternary deposits.

ESTIMATES OF TONNAGE AND VALUE.

In the 2.5-acre tract at Elmwood Road station the thickness of the marl is about 50 feet and its potash content 6.50 per cent. On the assumptions, as in previous estimates, of 28 per cent of voids and a weight of 133 pounds per cubic foot, 1 acre of this tract would contain $\frac{43{,}560 \times 50 \times 133 \times 0.065}{2{,}000} = 9{,}400$ tons of potash (K_2O) and the 2.5-acre tract would contain 23,500 tons.

With an 80 per cent recovery and a price of $2.50 per unit of 20 pounds (March, 1920) the potash in a ton of greensand would be worth $13 and the potash in an acre of this tract would be worth $1,880,000. At the more probable price of $1.50 per unit the potash in a ton of greensand would be worth $7.80 and the potash in an acre of the ground would be worth $1,128,000. These estimates of value have no relation to the present value of the land, as they are dependent upon the extraction of the potash by processes whose successful operation has not been commercially demonstrated.

UTILIZATION OF THE DEPOSITS.

The 2.5-acre tract is part of a tract large enough for commercial development and lies on a railroad that gives direct access to Delaware River at Camden, about 16 miles distant.

At holes 15 and 16 and at the Atlantic Potash Co.'s pits water rises within a few feet of the surface and will need to be considered in any plan for exploitation of the marl.

Along the southeast boundary of the marl belt a thickness of about 50 feet of marl may be expected, but the overburden is relatively thick, being about 17.5 feet in the 2.5-acre tract. Where streams have removed some of the overburden, as in the vicinity of the Atlantic Potash Co.'s pits, the marl will be more accessible.

MEDFORD DISTRICT.

MARL LOCALITIES.

The Medford district merges with the Marlton district on the west and is discussed separately only for convenience in the presentation of data. At Medford the Manasquan marl underlies the surface sand and gravel, but to the south, east, and northeast the Kirkwood is found. The Manasquan forms a belt extending nearly 4 miles southwest of Medford, but the marl is only locally exposed. It was formerly dug here and there, as at locality 78, about 1 mile southwest of the town. This locality was visited by Dr. Kümmel in September, 1917, when he found the pits entirely grown up with trees and no marl visible. The marl was deeply buried by yellow sand and must have lain 12 to 15 feet below the surface.

Just north of Medford the Vincentown sand forms a belt about a mile wide that is also largely concealed by surface sand and gravel. From the vicinity of Reeves station to a point within a mile of Lumberton the Hornerstown and Navesink marls occupy a belt about 2 miles wide, in which the marl lies under varying amounts of sand and gravel and in some places is within a few feet of the surface.

WELL DATA.

The records of several wells show the thickness of the overburden and of the marl in different parts of the district. The writer is indebted to M. W. Twitchell for the following record and interpretation of the well of J. S. Wills:

Record of well of J. S. Wills, near Medford (locality 79).

[Elevation, 63 (?) feet.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Soil	2	2	Kirkwood.
Clay, yellow sand	3	5	
Fine gray sand with greensand grains	10	15	
Coarse gray sand with greensand grains	8	23	
Olive-colored marl		30	Manasquan.
Dark-green marl		35	
Lime sand, Foraminifera, Bryozoa		50	Vincentown.
Green marl with shells (*Gryphaea* and *Terebratula*)		70	Hornerstown and Navesink.
Pure greensand, dark		76	
Pure greensand, light		80	
Pure greensand, dark		91	
Pure greensand, chocolate-colored		104	
Pure greensand, dark green		120	
Gray sand with greensand grains and shell, etc., *Exogyra* and *Belemnites*.		124	Mount Laurel and Wenonah.
Gray sand and water		126	

This record shows a thickness of about 54 feet of Hornerstown and Navesink marl beneath an overburden of 70 feet; but included in the overburden are about 20 feet of Manasquan marl and 20 feet of Vincentown sand.

At the farm of I. W. Stokes (locality 80), about 1 mile northeast of Medford, a well was sunk in the midst of the Hornerstown and Navesink marl belt. This shows 15 feet of overburden and 30 feet of marl, a commercial quantity. The following record and interpretation are supplied by Dr. Twitchell:

Record of well of I. W. Stokes, near Medford (locality 80).

[Elevation, 78 feet. Stotthoff Bros., drillers.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Sand and earth	15	15	
Marl	30	45	Hornerstown and Navesink.
Sand, varying	15	60	Mount Laurel and Wenonah.
Shelly layers	4	64	
Coarse gray sand (water irony)	6	70	
Green marl	15	85	
Black quicksand	25	110	
Marl	12	122	Marshalltown.
Quicksand	35	157	
Marl (fourth stratum) at		170	
Sand, some clay	5	175	Englishtown.
Sand, some clay (water good)	2	177	
Sand	6	183	

At the Eayrestown School, about 1.2 miles northea
town, a well was sunk, which, according to the State
furnishes the following record:

Record of well at Eayrestown School (locality 81).

[Elevation, about 45 feet. S. J. Taylor, driller.]

	Thickness.	Depth.	
	Feet.	*Feet.*	
Yellow sand	5	5	[Q
Brown and yellowish sandy loam	15	20	
Black marl, "gunpowder"	20	40	[H
Dark-green marl	10	50	
Hardpan, limestone	1	51	
Fine greenish sand, water	10	61	[M
Hardpan, "concrete"	1	62	
White sand, water	14	76	

The overburden at this site is relatively thick (20 feet
is 31 feet thick and from the descriptive terms used i
good quality. In view of the thickness shown it is prob
marl extends farther northwest than is shown on the ma

R. S. RYAN CO.'S PIT.

The pit of the R. S. Ryan Co., which formerly belong
Rogers, of Medford, is at Reeves station, about 2 miles
ford (locality 82), and is now the site of a plant for the
potash from greensand marl. (See Pl. IX, *A*.) At t
of the pit the following section was observed in March,

Section at pit of R. S. Ryan Co., at Reeves station (locality

	Thickness.	Depth.	
	Feet.	*Feet.*	
Brown soil with pebbles	2	2	Qu
Light-colored consolidated glauconitic sand	1	3	
Iron stone, full of shell casts and with local strongly ferruginous bands.	3	6	H
Black to greenish marl (1 inch strongly ferruginous layer at base).	1-1½	7½	
Black marl with greenish streaks	3	10½	

The pit has been dug below the level of the base of t
tion, but the lower part is concealed by water. The m
be 40 feet thick and to contain from 6½ to 7 per cent of
Material from the lower layer in the section was used
determinations described on page 19. An average sa
marl from this layer analyzed in the Survey laborato
6.25 per cent of potash.

The ironstone layer, which in the above section c
the position of the shell bed at the top of the Hornerst

C. PIT AT FARMINGDALE, MONMOUTH COUNTY, N. J.

ıerly owned and operated by Squankum Marl Co.; now owned by D. Mahoney. View northwest showing present overgrown and flooded condition.

thinner southward and is only about 6 inches thick at the south end of the pit. At that place the shells are missing, and the ironstone includes pebbles. Thus the ironstone appears to cut across the upper beds of the marl at a faint angle, rising toward the north.

The layer from which the sample analyzed came is in the upper part of the Hornerstown marl. Comparison with the borings previously described would indicate that marl of better quality would be found a few feet lower.

LIME SAND.

The Vincentown sand with its lime-sand phase is reported in the logs of some of the wells already cited. In this district it is exposed only in the pit at locality 83, on Haynes Creek about 0.4 mile southeast of the R. S. Ryan Co.'s pit just described, with which it is connected by a tramway. The lime-sand pit also belongs to the R. S. Ryan Co., and the lime sand is used with the greensand in the process of potash extraction.

The exposure shows about 8 feet of lime and quartz sand with hard, cemented masses of lime sand 6 inches to 1 foot thick, irregularly distributed through it. There are also large bodies of dark-greenish clay, grading into sand and here and there containing small masses of limestone. Clay bodies 10 feet or more long and 2 or 3 feet thick lie near the base of the cut. A random sample of the loose lime sand analyzed in the Survey laboratory contained 35 per cent of carbonate of lime ($CaCO_3$), and a similar sample of the harder limestone phase contained 74 per cent. The analysis of the harder sample gave 52 per cent of lime (CaO), of which only about 32 per cent is in the carbonate form. The excess lime, 20 per cent, is probably present as phosphate, for a qualitative test shows a strong reaction for phosphoric acid. Some iron is also present and may be combined with carbon dioxide (CO_2). The loose lime sand contains only a small excess of lime. The presence of phosphate of lime in the lime sand may account for its irregular consolidation and also in part for its beneficial action in agriculture.

VINCENTOWN.

Vincentown lies partly in the area of the Manasquan marl and partly in that of the Vincentown sand. Both marl and lime sand have been dug near the town, but these formations are only locally exposed.

WELL DATA.

A few wells sunk near Vincentown give an idea of the amount and character of the overburden and of the thickness of the lime sand and marl beds. The well of William J. Irick, about a mile west of

Vincentown, penetrates the Navesink marl and shows the succession of overlying beds. Its record follows:

Record of well of William J. Irick, about 1 mile west of Vincentown (locality 84).[a]

[Elevation, 30 feet. A. G. Dunphey, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Yellow gravel	3	3	[Quaternary.]
Orange-colored sand and fine gravel	6	9	
Yellowish sand with a few greensand grains	9	18	[Vincentown.]
Yellowish lime sand with plentiful Bryozoa	7	25	
Ash-colored lime sand with very few Bryozoa	19	44	
Grayish greensand with numerous Foraminifera, Bryozoa wanting	5	49	
Dark greensand with *Terebratula harlani* and *Gryphaea*	1	50	[Hornerstown and Navesink.]
Lighter-colored greensand; no fossils	20	70	
Very dark colored greensand	31	101	
Grayish greensand with fossils, including *Gryphaea* and *Belemnitella*	3	104	
Grayish greensand with *Belemnites*	5	109	Mount Laurel ?).

[a] New Jersey Geol. Survey Ann. Rept. for 1901, p. 71.

Here beneath an overburden of 18 feet of sand and gravel, including probably the upper bed of the Vincentown, there are 31 feet of lime sand and 55 feet of greensand marl, including both shell beds.

A well sunk at Richard Ridgway's farm, south of Vincentown, shows, as reported, some 90 feet of marl beneath 12 feet of overburden. Its record follows:

Record of well of Richard Ridgway, about 1.75 miles south of Vincentown (locality 85).[a]

[Elevation, about 40 feet. S. J. Taylor, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Low soggy ground	12	12	[Quaternary.]
Dark-green marl	20	32	[Manasquan and Vincentown?].
Light-green marl	70	102	
Oyster shells, hard stone, some greensand	10	112	[Top of Hornerstown?

[a] Files of New Jersey Geol. Survey.

This well is about 2 miles farther down the dip than the Irick well and would thus be expected to show a greater thickness of the Vincentown sand, which is locally very glauconitic, and a complete or nearly complete thickness of Manasquan marl. The limesand phase of the Vincentown, if present, was not recognized. It is possible that the Vincentown is absent and that the shell bed mentioned is the base of the Navesink, but in view of the records of the Irick well and that of Henry I. Budd, given below, the interpretation indicated seems more probable.

The well of Edward Blackley, at locality 86, near that of Richard Ridgway, shows a similar record but was sunk to a depth of 135 feet. The driller reports that the oyster shells were not so plentiful and that a little black muck was penetrated before reaching the sand, which was of a gray color.

The well of Henry I. Budd,[30] described as 2 miles south of Birmingham, is probably within 2 miles of Vincentown and somewhat northwest of the strike of the beds at the two wells last mentioned. At the Budd well the base of the Navesink is struck at the depth of 140 feet. Its record follows.

Record of well of Henry I. Budd, 2 miles south of Birmingham.

[Elevation, 50 feet.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Loam and clay	7	7	
Marl, sticky	62	69	
Hard ironstone	2	71	
Marl	1	72	[Vincentown?]
Hard crust	1	73	
Marl	2	75	
Hard crust	1	76	
Marl	3	79	
Hard crust	1	80	
Marl	2	82	
Hard crust	1	83	
Marl	2	85	
Hard crust	1	86	
Marl	3	89	
Shell marl	10	99	
Shell bed, *Gryphaea* and *Terebratula*	6	105	[Hornerstown and Navesink.]
Black sand and marl	10	115	
Greensand marl	23	138	
Crust, *Belemnites*	2	140	
Coarse white sand with water	3	143	[Mount Laurel and Wenonah.]

In this well the position of the top of the Hornerstown is clearly indicated by the *Terebratula*-bearing bed, and the combined Hornerstown and Navesink beds are thus 41 feet thick. The alternating marl and crust layers above this bed are suggestive of the lime-sand and limestone phases of the Vincentown, which under this interpretation would be 28 feet thick. The 62 feet of "sticky marl" is probably too thick to represent only the Manasquan marl and may include the lower and more clayey portion of the Kirkwood. The ironstone, however, suggests unconformity, so that the Manasquan may be absent.

MARL PITS.

At locality 87, about 1 mile south of Vincentown, on the property of Dr. J. Clifford Haines, Dr. Kümmel observed, in September, 1917,

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[30] New Jersey Geol. Survey Ann. Rept. for 1896, p. 143, 1897.

a freshly dug pit with vertical walls in which the following section was exposed:

Section at marl pit of Dr. J. Clifford Haines, 1 mile south of Vincentown (locality 87).

	Feet.
Sand and gravel	5
Crusty marl	1
Gray to black marl	3–4
Water level.	
	10

Other exposures in the neighborhood showed 10 to 12 feet of stripping.

In the early eighties, according to data on file at the New Jersey Geological Survey, the pits of the Vincentown Marl Co., which were near the Haines pit, showed an overburden of 6 feet of yellow and white sand and gravel resting on 15 to 20 feet of marl, gray above and black below.

At locality 88, on the opposite side of the creek from locality 87, Dr. Kümmel observed, in September, 1917, several small openings that had been made within the preceding few years. There were piles of light ash-colored marl at an elevation of about 40 feet, and the pits showed 7 or 8 feet of sand and gravel overlying 3 to 4 feet of light yellowish-green marl blotched with clayey pellets. The pits were filled with water.

The pits on the H. J. Budd estate, at locality 89, about 1½ miles east of Vincentown, were visited by Dr. Kümmel in September, 1917. No marl had been dug there for 20 years, and there were no exposures, but according to John W. Rose, who used to dig marl there, the pits formerly showed 3 to 6 feet of stripping succeeded by 3 feet of gray marl (locally with ironstone) overlying 12 to 18 feet of black marl. The bottom of the marl was not reached.

From the Ben Brown place, near Vincentown, W. C. Phalen collected a sample of marl from a previously dug pile and a check sample from a bed of greensand 5 or 6 feet thick. The first sample when analyzed in the laboratory of the United States Geological Survey was found to contain 3.74 per cent of potash and the second sample 4.22 per cent.[21] A third sample from the Henry Butterworth place, between Pemberton and Vincentown, contained 4.28 per cent of potash. This sample represented 5 feet of greensand, which was overlain by 10 to 15 feet of clay and gravel.

LIME SAND.

According to data on file at the State Survey, lime sand was dug on Rancocas Creek near Vincentown at locality 90. In the early eighties the following section was exposed:

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[21] Ashley, G. H., Notes on the greensand deposits of the United States: U. S. Geol. Survey Bull. 660, pp. 39, 47, 1918.

Section of Vincentown sand on Rancocas Creek, near Vincentown (locality 90).

	Ft.	in.
Brown sand and humus		6
Yellow and white sand and marl	2-4	
Red sand		6
Lime sand, cemented in some places and full of *Eschara*	7-9	
Limestone	10	
	24	

In the spring of 1919 interest in the lime sand at Vincentown was revived, and some of the material was reported as being dug for agricultural lime.

BIRMINGHAM AND PEMBERTON.

HOFFMAN PIT.

William Hoffman owns a large pit at Birmingham (locality 91), from which he makes occasional shipments. (See Pl. IX, *B*.) The following section was exposed in January, 1919:

Section at William Hoffman's marl pit, at Birmingham (locality 91).

	Ft.	in.
Sand with some pebbles	6	
Light-green clay locally at contact		1-2
Marl, grayish, with some dark irregular masses including gray spots and specks	2-3	
Marl, black, grading irregularly into overlying layer	3	6
Marl, black, dark greenish tint	1	6
	14	2

Mr. Hoffman states that the marl about 14 feet below the top is green and that he stops digging at that depth on account of water. A sample representing an average of 10 feet of greensand from this pit, taken by W. C. Phalen in 1917 and analyzed in the Survey laboratory, contained 7.07 per cent of potash (K_2O).[32]

A well sunk for Mr. Harper at locality 92, a short distance south of the Hoffman pit, shows the thickness of the marl and the amount of overburden that may be expected. Its record follows:

Record of Harper well, about 0.33 mile N. 24° W. of Birmingham station (locality 92).

[Elevation, about 30 feet. S. J. Taylor, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Sand and gravel	15	15	Quaternary.
Ironstone, very hard	2	17	
Light-gray to dark-green marl	33	50	Hornerstown and Navesink.
Hard sandstone formation (indurated marl?)	10	60	
Oyster and clam shells, "lignite," coral reef, etc	10	70	
Shell, brown sand, white sand	20	90	Mount Laurel and Wenonah.
Brown clay	5	95	

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[32] Ashley, G. H., op. cit., p. 47.

According to Mr. Taylor, the "lignite" of the above record is glauconite. The total thickness of the marl beds as there shown is 53 feet, and that of the overburden is 17 feet. The shell bed at the base of the Navesink, which lies at a depth of 60 feet in the well, is exposed in the bank of the creek above 12 feet of Mount Laurel sand at locality 93, about 1.2 miles north of Ewansville.

PITS OF NORCROSS & EDMUNDS CO.

About half a mile east of Birmingham station the Norcross & Edmunds Co. has operated a sand-washing plant for a number of years. The sand is taken from the company's property, which includes about half a square mile south of the creek and east of the station. So much sand has been removed that the overburden over much of that area has been greatly reduced. The property lies largely in the belt of Vincentown sand, but the creek has cut through into the marl about 0.2 mile east of the station, and near the western part of the property the Vincentown sand should not be very thick.

Men and tools were kindly supplied by the company for exploration, and three attempts were made to reach the marl in the vicinity of localities 94 and 95, but each attempt was unsuccessful because of the gravelly nature of the overburden and the nearness of water to the surface. The marl was not reached at depths of 3 or 4 feet.

In the southeastern part of the property two holes, Nos. 17 and 18, were sunk, respectively, at localities 96 and 97 in the Manasquan marl, and samples for analysis were taken. The character and potash content of the material are shown in the table below.

Two attempts were made to sink a third hole by the creek at locality 98, but these were abandoned at depths of 3 or 4 feet because of the gravelly nature of the overburden and the abundance of water.

Records of holes at sand pits of Norcross & Edmunds Co.

Locality 96, hole 17.

[About 0.75 mile southeast of Birmingham station and about 375 feet northwest of culvert in road to South Pemberton. Elevation of present surface, about 50 feet. Analyst, E. T. Erickson.]

	Thickness.	Depth.	Field No. of sample.	K_2O.	Formation.
	Ft. in.	*Ft. in.*		*Per cent.*	
Gravel with pronounced iron-stained layers.....	3	3	....	....	Pleistocene.
Glauconite beds, thin alternating leafy layers of drab fine sandy clay and greenish glauconitic clay; random sample.	3 3	6 3	M-119a	3.63	Manasquan.
Glauconite beds, dark grayish green, clayey, uniform texture, water bearing.	9 8	15 11	M-119	3.61	Do.

Locality 97, hole 18.

[About 330 feet north of hole 17. Elevation of surface, about 50 feet. Analyst, E. T. Erickson.]

	Thickness.	Depth.	Field. No. of sample.	K_2O.	Formation.
	Ft. in.	*Ft. in.*		*Per cent.*	
Gravel and sand	8	8	......	....	Pleistocene.
Glauconite beds, thin alternating leafy layers of drab fine sandy clay and greenish glauconitic clay. Random sample taken at depth of 9 feet considered representative of entire bed. Lower 6 to 8 inches a little darker and more clayey.	14 4	15	M-120	3.27	Do.
Glauconite beds, clayey, dark greenish gray	2 10	17 10	M-121	2.75	Manasquan.
Glauconite beds, light greenish gray, with grains of lime and lumps of vivianite. Lumps are irregular in shape and rough in feel. The bed has much clay and considerable glauconite but appears quite limy with dark glauconite streaks. At base a hard layer that could not be penetrated with auger. Top of Vincentown(?). Water stands in hole about 3 feet below surface.	1 8	19 6	M-122	1.83	Do.

At locality 99, in the same general vicinity, a hole 10 to 15 feet square and perhaps 10 feet deep, now filled with water, had been recently dug in the Vincentown sand. No greensand appeared on the dump, but incoherent lime sand with some pieces of cemented limestone formed the bulk of the pile. Bryozoa were very numerous. Portions of the material were strongly cemented with iron oxide, and much vivianite was scattered over the dump in bluish radiating crystalline masses, in crusts, and in concretionary forms. Evidently the hole had missed the Manasquan marl and had not been dug deep enough to strike the Hornerstown.

From the vicinity of this hole westward and northward to the railroad the lime sand should be relatively near the surface and in sufficient quantity to be a commercial source in the event of any exploitation of greensand marl in the district. No analyses of this material are available, but from its appearance in the dump near the hole and in débris along some of the ditches cut by the company it seems probable that this lime sand will compare favorably in content of carbonate of lime with that from locality 83, near Reeves station, which is utilized by the R. S. Ryan Co.

The Norcross & Edmunds Co. also owns ground between Rancocas Creek and the road east of the tributary that enters the creek about 0.6 mile southeast of South Pemberton station. Through the courtesy of the company a hole, No. 19, was sunk at locality 100, in the northwestern part of this property. There are numerous old marl pits in the vicinity, and some recent pits with equipment for digging. A site was selected near one of the recent pits where most of the overburden had been removed, and samples for analysis were collected, as shown in the following record.

Record of hole 19, at locality 100.

[On property of Norcross & Edmunds Co. about 4,200 feet S. 65° E. from South Pemberton station, at group of old and recent marl pits. Elevation of present surface, about 36 feet. Analyst, E. T. Erickson.]

	Thickness.	Depth.	Field No. of sample.	K_2O.	Formation.
	Ft. in.	*Ft. in.*		*Per cent.*	
Soil and gravel at level of former working	1	1	....	....	Pleistocene,
Glauconite beds, dark grayish green, somewhat clayey, fine textured, rather mealy.	5	6	M-123	4.29	Manasquan.
Glauconite beds, lighter green, stiff, clayey; contain considerable quartz in fine grains, greasy feel and appearance on smooth surface.	2	8	M-124	2.99	Do.
Glauconite beds similar to last but with more quartz and somewhat mealy texture: irregular streaks of lighter and darker constituents.	3 10	11 10			
Glauconite beds, darker green, larger percentage of glauconite due to larger number of thin beds of fine-textured glauconite.	6	12 4			
Glauconite beds, dark green, thin bedded, with numerous layers of fine glauconitic material; at base a stiff green clay.	3 8	16	M-125	4.61	Do.

The overburden at the hole was only 1 foot thick, but the top of the hole was about 3 feet below the level of the adjoining meadow to the northeast. The marl was not penetrated at the depth reached, 16 feet.

The analyses of the marl from holes 17 to 19 indicate that the portion of the Manasquan represented by them is distinctly inferior in potash content to the Hornerstown and Navesink marls. Determinations of the water-soluble potash of the samples from these holes showed either none or a mere trace.

Composite samples from these holes were tested for their content of lime (CaO) and of phosphoric acid (P_2O_5), with the results shown in the following table:

Potash, lime, and phosphate content of samples of Manasquan marl from holes on property of Norcross & Edmunds Co., near Birmingham and South Pemberton (localities 96, 97, and 100).

[Analyst, E. T. Erickson.]

Field No. of sample.	Thickness.	K_2O.	Soluble K_2O.	CaO.	P_2O_5.
	Ft. in.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
M-119a	3 3	3.63	Trace	1.53	1.37
M-120	14 4	3.27	None		
M-119	9 8	3.61	Faint trace	2.31	3.58
M-121	2 10	2.75	None		
M-122	1 8	1.83	.....do		
M-123	5	4.29	Trace	3.86	2.44
M-125	3 8	4.61	.....do		

The lime and phosphate content of this marl, as indicated by the above analyses, is not high but is probably sufficient under favorable conditions to produce beneficial results in agriculture. The higher phosphate content of the middle group is probably due to the vivianite in sample 122. (See p. 87.)

OTHER DATA.

At North Pemberton a well sunk near the station for Peter Cosgrove's creamery furnishes the following record:

Record of well at Peter Cosgrove's creamery, North Pemberton (locality 101).

[Elevation, about 35 feet. S. J. Taylor, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Dug well	15	15	Manasquan and Vincentown(?).
Dark-green marl	65	80	
Shells, very hard	2	82	Hornerstown and Navesink (?).
Coarse greensand and quartz	6	88	
Green marl, "lignite" (=glauconite)	18	106	
Black micaceous clay	20	126	
Hard shells	6	132	
Coarse white quartz	10	142	Mount Laurel and Wenonah.

The 65 feet of green marl in the upper part of this well is rather hard to interpret. The Vincentown locally contains much greensand and at some places, as at hole 16 (locality 63), might be called a greensand marl. The lime-sand phase does not appear to have been recognized here and may be absent, in which event the Manasquan and Vincentown might together form the "green marl." The two shell beds give rather definitely the position of the combined Hornerstown and Navesink beds, and, allowing for the dip, the lower shell bed is at about the right depth to correspond with its position at localities 92 and 93. With this interpretation the combined Hornerstown and Navesink marls would be 52 feet thick.

At locality 102, near South Pemberton, are some old pits now overgrown. According to data on file at the State Survey, the following section was formerly exposed here:

Section exposed in the early eighties at marl pits near South Pemberton (locality 102).

	Feet.
Humus and black sand	1
Yellow sand and gravel	3
Reddish-brown sand	1½
White, black, and yellow sand and gravel	1¼
Marl with scattered shark teeth	18
	24¾

At locality 103, about 2 miles northeast of Pemberton, are some marl pits from which Ivins Horner made small shipments in 1914. This locality was visited by Dr. Kümmel in September, 1917, when he observed the following section:

Section at pits of Ivins Horner, 2 miles northeast of Pemberton (locality 103).

	Feet.
Stripping	3–4
Gray marl	2–2½
Green marl	10
	16½

The marl pits occupy 2 or 3 acres dug over in rows. A large area can be opened to the south without much increase in stripping. The bottom of the marl was not reached, but the green marl is said to be 18 feet thick.

A sample of marl taken by W. C. Phalen from one of the piles was analyzed in the laboratory of the Geological Survey and found to contain 4.22 per cent of potash. A second sample taken from a bed where the greensand was 12 to 14 feet thick and the overburden 8 to 10 feet thick contained 4.74 per cent of potash.[33]

SUMMARY.

Near Birmingham there are several places in proximity to the railroad where Hornerstown and Navesink marl of suitable quality can be obtained in commercial quantities without too much overburden. Lime sand is also accessible near the railroad between Birmingham and Pemberton. The Manasquan marl near Pemberton is apparently 18 feet or more thick but so far as examined carries less potash than the Hornerstown and Navesink marls. The presence of small amounts of lime and phosphoric acid (P_2O_5) probably explains its former popularity in agricultural use. The overburden is rather thick except along stream courses.

The available data do not warrant the formulation of specific tonnage estimates for the potash content of the areas described.

OTHER AREAS.

Although no further boring was done than that described, well records and fairly recent data bearing on the thickness and continuity of the marl are available for several other areas northeastward into Monmouth County. These are given below.

JOBSTOWN.

The well of Barclay White at Jobstown, locality not stated, shows that the marl continues into that district in probable commercial quality and thickness.

Record of well of Barclay White, Jobstown.

[W. C. Barr, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Dug well	14	14	[Hornerstown and Navesink].
Green marl	10	24	
Black marl and shells	46	70	
Coarse gray or paper-colored sand, a few inches water bearing.			[Mount Laurel and Wenonah.]

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[33] Ashley, G. H., op. cit., pp. 39, 47.

A railroad traverses the marl belt southeast of Jobstown and affords suitable transportation facilities. The overburden in the higher lands along the railroad is probably excessive, but along the stream courses more favorable sites for exploitation may be expected. For example, a site near the stream and railroad crossings below Juliustown (Ellis station) would probably give a maximum of marl with a minimum of overburden. The lime sand occurs at Juliustown but is not well exposed.

SYKESVILLE.

In the vicinity of Sykesville the Hornerstown and Navesink marls become separated by the Redbank sand. A well sunk for the Newbold Black estate at locality 104(?), about 1 mile north of Sykesville, shows 15 feet of Navesink marl beneath 35 feet of gray sand.

At locality 105, about halfway between Sykesville and Georgetown, a well sunk for D. C. Kalback on timber land at an elevation of about 135 feet penetrated the base of the Navesink marl at a depth of about 81 feet. No specific record of this well is available, but material lying on the dump consisted chiefly of Navesink marl and Redbank sand with apparently a very good representation of the Navesink.

WRIGHTSTOWN.

At locality 106, about 0.9 mile north of Wrightstown station, a well sunk for Ellis (Robert?) Crowshaw furnishes the following record:

Record of well of Ellis Crowshaw near Wrightstown (locality 106).

[Elevation, about 160 feet. S. J. Taylor, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Very hard yellowish clay and gravel	15	15	[Quaternary and Tertiary.].
Greensand, "something like Englishtown"	5	20	
Hard concrete formation, sandstone	10	30	[Vincentown?]
Very dark bluish marl and shells	20	50	[Hornerstown and Navesink.]
Light-green sand, shelly marls	40	90	
Very dark greenish marl, shells	20	110	
Hard gray sand, shells, hardpan containing *Belemnitella*, underlain by dry black micaceous clay; water.	20	130	[Mount Laurel.]

The overburden here is 30 feet thick, of which the 10 feet of "hard concrete" may represent the limestone or lime-sand phase of the Vincentown. The marl appears to be 80 feet thick but may include beds assignable to the Redbank sand. The sand with *Belemnitella* is undoubtedly Mount Laurel.

On January 18, 1918, two wells were being drilled at an elevation of about 120 feet at locality 107, on the bank of the creek about three-eighths of a mile northwest of the station at Wrightstown.

At that date one well was 130 feet deep and the other 320 feet. No definite record was kept, but Dr. Kümmel's inquiries elicited the following data:

Records of two wells about 0.38 mile N. 64° W. of Wrightstown station (locality 107).

	Thickness.	Depth.
	Feet.	*Feet.*
Soil, flood-plain deposits, etc	9	9
Marl	101	110
Shell bed, *Exogyra*, *Belemnitella*	2	112
Greenish quartz sand with more or less marl	13	125
Other beds	195	320

Dr. Kümmel notes that the shell bed is undoubtedly the base of the Navesink marl. He thinks that part of what is reported as marl is Vincentown sand. The Kirkwood sand appears in the side slopes of the valley above the wells. From a contact of Navesink and Mount Laurel 3 miles away Dr. Kümmel estimates the dip here at 38 to 40 feet to the mile.

JACOBSTOWN.

At locality 108, along the road about 1.4 miles east of Jacobstown, the shell bed at the top of the Hornerstown is exposed in the stream bed north of the road. A considerable acreage of comparatively even ground with probably moderate overburden and with practically the full thickness of the Hornerstown marl is here available. Unfortunately the site is about 1½ miles from the nearest railroad shipping point, New Egypt.

At locality 109, about 1.1 miles farther northeast, on the road and county line, the shell bed at the top of the Hornerstown is exposed. Dr. Kümmel notes that the overlying Vincentown sand is a gray, more or less marly sand, more strongly marly in its lower 10 or 12 feet than in higher beds. At a pit nearby he observed the following section:

Section at pit near county line west of Crosswicks Creek, Monmouth County.

	Feet.
Vincentown sand	
Black greensand	6
Greensand with yellowish pebbles 1 inch in diameter, not so much clayey as limy in appearance	6
Greensand, very black and massive, base not exposed	6
	18

NEW EGYPT.

The following record of a well drilled for the water company at New Egypt[34] shows a probable great thickness of marl but does not differentiate the greensand from the Vincentown, in which it begins.

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[34] New Jersey Geol. Survey Ann. Rept. for 1909, p. 85.

Record of well of water company at New Egypt.

[Elevation, 75 feet; Pfeiffer, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Marl	112	112	[Vincentown to Navesink.]
Sand	8	120	[Mount Laurel to Marshalltown?]
Marl	98	218	
Dark quartz sand	20	238	[Englishtown.]

The base of the Navesink is probably at the depth of 112 feet. Its thickness combined with that of the Hornerstown doubtless exceeds 50 feet.

About 1 mile south of New Egypt the Manasquan marl forms an irregular area in which a number of old marl pits are located. These are mostly inactive and overgrown, but at some of them marl has been dug as late as 1915. In October, 1913, Dr. Twitchell[35] observed the following section at the Huggins pit:

Section at Huggins marl pit, about 1½ miles south of New Egypt.

	Feet.
Soil, gray sandy, with a few pebbles	2
Marl, olive green, apparently reworked, yellow spots and streaks	4
Marl, dark olive green to greenish black, pale-yellow specks and concretions	4
	10

Some marl was dug here in 1912–13. The surface where dug looks like fine light-gray ashes.

HORNERSTOWN.

At locality 111, about 0.75 mile southwest of Hornerstown, there is a large marl pit, formerly worked on an extensive scale and connected with the railroad by a spur track. This pit was visited in 1917 by Dr. Kümmel, from whose field notes the following observations are taken:

> The old marl pit is now grown up with sizeable trees. The old switch is now torn up, but the graded cut is still available. The marl is fairly well shown on the sides. On the south side it lies within 1 or 2 feet of the surface and is covered with sand, with a line of pebbles at the base. If the marl extends to the bottom of the pit its thickness must be in excess of 20 feet. The excavation can be extended southward for several rods and northward an equal distance without increase of thickness of cover. East of the railroad is a broad field of 20 to 40 acres, or perhaps more, in which the marl probably lies very near the surface. This is one of the best pits. It is now owned by the Richard Miers estate. Some marl has been dug at Hornerstown within recent years, but none has been sold.

Along Crosswicks Creek and in some of its branches the marl is exposed here and there within 1 or 2 miles of Hornerstown. At

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[35] Data on file at New Jersey Geological Survey.

locality 112, in a tributary opposite Lahaway Creek, the basal bed of the Navesink is exposed on both sides of the creek east of the road, and characteristic fossils, including *Belemnitella*, may be found in it.

A well sunk for Charles Higgins near and southwest of the mill pond at Hornerstown furnishes the following record, which is given both as reported and as here interpreted.

Record of well of Charles Higgins, southwest of mill pond at Hornerstown (locality 113).

[Elevation, 20 feet (above pond?); F. R. Hope. driller.]

As reported.		As interpreted.		
		Thickness.	Depth.	Formation.
	Feet.	*Feet.*	*Feet.*	
Green marl at about	12	12	12	Quaternary(?).
		22	34	Hornerstown.
Black marl at about	34	15	49	Redbank(?).
Second stratum of iron or something tough to penetrate at	42			
Gray marl at	49	24	73	Navesink(?).
Coarse sand at	73	2	75	Mount Laurel(?).

As above interpreted the well shows 22 feet of Hornerstown marl beneath 12 feet of overburden. The base of the Navesink is probably at a depth of 73 feet. The zone between the Hornerstown and Navesink, as exposed in the ravine at locality 114, is black, glauconitic, and micaceous and might be called a black marl.

CREAM RIDGE AND DAVIS.

A railroad traverses the Navesink marl between Cream Ridge and Davis and could supply transportation for marl or marl products, in case of any commercial development. A pit at locality 115, about 0.45 mile east of Davis, shows the following section:

Section at marl pit 0.45 mile east of Davis (locality 115).

	Feet.
Fine reddish and yellowish sand	6
Black micaceous sand with some clay pellets and greensand; scattered large shells (*Gryphaea*)	10–11
	17

There is a distinct iron-bearing zone between the two beds of sand, forming a dark line on the weathered face of the pit. This is probably the contact between the Redbank sand and the underlying Navesink marl, the base of which is not exposed.

MARLBORO.

The Navesink marl was dug in large quantities many years ago at Marlboro and Holmdel and along branches of Hop Brook east of Marlboro. There are some very large pits in this vicinity, but most

of them are now inactive and more or less overgrown. From time to time small amounts of marl are dug for local use.

The United States Department of Agriculture has recently arranged for a shipment of three carloads of greensand marl from Marlboro to Florence, S. C., for experimental use on lands deficient in potash. (See pp. 113–115.)

The following rather recent analyses of Navesink marl from the vicinity of Marlboro give a good idea of the phosphoric acid and potash content of what may perhaps be called random or run of mine samples:

Analyses of samples of Navesink marl from Marlboro and vicinity.[a]

[Collected by C. C. Engle, representing the New Jersey Geological Survey.]

No.	Location.	P_2O_5	K_2O
		Per cent.	*Per cent.*
1	Pit of Mr. Stryker, Marlboro	0.82	5.06
2	do	1.20	5.44
3	do	1.05	5.70
4	Pit of Charles M. Wyckoff, Marlboro	1.10	6.50
5	do	.94	6.28
6	Pit of Joseph Holmes, Holmdel	.73	6.05
7	Pit of Mr. Myers, Marlboro	1.21	4.24
8	Pit of David I. Van Deveer, Marlboro	.64	5.05
9	Pit of D. H. Taylor, Bradevelt	.99	4.64
10	do	.39	6.16
		.907	5.512

[a] Blair, A. W., The agricultural value of greensand marl: New Jersey Agr. Exper. Sta. Circ. 61, p. 12, 1916.

At the John Van Kirk place, at Marlboro, where 10 feet of greensand containing shells is overlain by 3 to 5 feet of gravel, W. C. Phalen collected a sample which was analyzed at the laboratory of the United States Geological Survey and found to contain 4.45 per cent of potash.[36]

The average potash content of the Navesink marl dug near Marlboro, if judged by the analyses in the above table, is 1.09 per cent lower than the average obtained from the borings at holes 1 to 16, as described above. (See also p. 104.) The phosphoric acid content of nearly 1 per cent would give the marl additional agricultural value.

Marlboro and Bradevelt are on the railroad, and the country in their vicinity is sufficiently level to permit exploitation of considerable areas. The Marlboro district is thus the most favorably situated of the Navesink localities for commercial development.

FREEHOLD.

The Hornerstown marl comes to the surface over extensive areas in the vicinity of Freehold. Marl was formerly dug here but on a less extensive scale than at Marlboro, and there has been little recent digging. Recent analyses, showing the phosphoric acid and potash

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[36] Ashley, G. H., Notes on the greensand deposits of the United States: U. S. Geol. Survey Bull. 660, pp. 39, 47.

content of random or run of mine samples from Freehold, are given in the following table:

Analyses of samples of Hornerstown marl from pit of J. W. Dobbins, Freehold.[a]

[Collected by C. C. Engle, representing the New Jersey Geological Survey.]

No.	P_2O_5.	K_2O.
	Per cent.	*Per cent.*
18	0.81	6.05
19	1.40	5.04
20	.67	5.12
Average	.96	5.40

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[a] Blair, A. W., op. cit.

The average phosphoric acid content of the three samples from Freehold is slightly higher than that of the ten samples from Marlboro, but the potash content is a little lower. These differences might disappear if a larger number of analyses were available.

Freehold, because of its railroad facilities, is one of the most favorable localities in Monmouth County for the commercial development of the Hornerstown marl.

EATONTOWN.

At Eatontown and about 3 miles to the east, at Branchport, the Hornerstown marl is crossed by railroads, and at Branchport it is on tidewater at Pleasure Bay, which cuts diagonally across the marl bed. Parker Creek, a branch of Shrewsbury River, also tidewater, lies along the northwest border of the Hornerstown bed.

At locality 116, about 0.3 mile north of Eatontown, according to field notes of Dr. Kümmel, the Hornerstown marl beneath a thin cap of gravel reaches an elevation of 25 to 28 feet in the road cut at the top of the hill and extends down 10 feet, to the level of the flood plain of the creek to the north, or even lower. Thus the maximum thickness of the marl near Eatontown is probably as much as 20 feet and may be more.

At locality 117, half a mile south of Shrewsbury, the road cut, according to Dr. Kümmel's notes, shows 6 to 7 feet of marl from 25 to 32 feet above sea level. The marl passes downward into a more or less indurated marly sand (Tinton) revealed only by boring. Thus the marl outcrop should be extended somewhat farther north than is shown on the map. The slope of the surface southward to the creek corresponds very closely with the dip of the marl bed.

The Eastern Potash Corporation has acquired of Charles McCue the Crystal Brook farm, about 75 acres, including land between the road and the railroad and on both sides of the brook half a mile north of Eatontown. It also has provisional options on land farther east. The following analyses of samples collected from these properties have been kindly supplied by Mr. T. C. Meadows, manager of the corporation:

Analyses of samples of greensand from vicinity of Eatontown.

[Analysts, Stilwell & Gladding, New York.]

No.		Total potash (K_2O).
		Per cent.
217490	Sample from military pig pen from Monmouth Park, received from the American Potash Corporation [a] July 30, 1918	8.75
217489	Greensand "from top of knoll beside nursery," received from the American Potash Corporation July 30, 1918	8.68
218045	Greensand marked "No. 7—6½ overburden, 14 feet blue and green marl," received from the American Potash Corporation, Aug. 15, 1918. On sample dried at 212° F	8.19

[a] The Eastern Potash Corporation has taken over the rights and patents of the American Potash Corporation, in so far as they relate to potash extraction from greensand.

In view of the results obtained from samples already cited in other parts of the marl belt these results seem high.

A sample of fresh marl, collected at a depth of 1 foot at locality 118, on the property of the Eastern Potash Corporation, was analyzed at the laboratory of the United States Geological Survey. It contained 7.09 per cent of potash (total K_2O), including a trace of soluble potash. This analysis, which may serve as a check upon the others, shows that the Hornerstown marl at Eatontown compares favorably with the better-grade marls elsewhere in the marl belt, but it shows also that the Eatontown material is perhaps not so conspicuously high in total potash as the analyses in the table would indicate.

According to field notes of Dr. Kümmel, the thickness of the Hornerstown marl at Crawford Hill (locality 119), about 8½ miles northwest of Eatontown is about 25 feet.

FARMINGDALE.

The Manasquan marl was formerly dug in considerable quantity in the vicinity of Farmingdale, in Monmouth County, and enjoyed a high reputation as an agricultural marl. The pit nearly half a mile northeast of the town (locality 120), now owned by D. Mahoney, is doubtless the largest. It has long been inactive and largely filled with water. (See Pl. IX, *C*.) The following section was measured by Dr. Kümmel [37] at the north end of the pit:

Section at D. Mahoney's marl pit, Farmingdale.

	Feet.
Pleistocene gravel	6
Laminated clay with very thin seams of sand, the laminae of sand more numerous and thicker in upper portion; the upper part of the exposure weathered to a yellow color; the lower 8 feet nearly black or very dark chocolate-colored; no glauconite. Kirkwood (Miocene)	12
Greensand marl composed of glauconite and very fine quartz sand; when wet material is plastic and coherent; only upper portion shown	2–3
	21

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[37] Kümmel, H. B., field notes on file at New Jersey Department of Conservation and Development.

The overburden at the north side of the pit is now 18 feet or more. It probably increases in that direction, but toward the northwest, southwest, and south probably considerable extensions of the pit could be made without finding much increase of overburden.

The Squankum pits, about 3 miles south of Farmingdale, which formerly produced much marl, are now flooded.

At the pits of James H. Johnson, about three-quarters of a mile southwest of Farmingdale (locality 121), Dr. Twitchell[38] in 1912 observed the following section:

Section at marl pits of J. H. Johnson, near Farmingdale.

	Feet.
Gray sandy soil	1
Yellow sand	1
Yellow sand and abundant gravel	1
Chocolate-colored clay, laminated	2–3
Light bluish green to olive-green marl	1
	7

The marl is light greenish gray when dry, piles of it resembling piles of ashes. In 1884 N. L. Britton visited these pits and noted the following section:[39]

Britton's section at Johnson marl pits in 1884.

	Feet.
Brown sand and humus	2
Yellow drift	3
Marl	15–17
	22

The excavations are in the ash and blue marl layers of the upper marl bed.

Small thicknesses of marl are exposed along the water's edge at several places along the river in the vicinity of the Johnson pits.

Several relatively recent analyses of marl samples from Farmingdale show something of the phosphoric acid and potash content of the Manasquan marl in that vicinity.

Analyses of samples of marl from Farmingdale.[a]

[Collected by C. C. Engle, representing the New Jersey Geological Survey.]

No.	Locality.	P_2O_5	K_2O
		Per cent.	*Per cent.*
11	Pit of P. S. Perry, Farmingdale	1.12	2.76
12	Pit of J. H. Johnson, Farmingdale	1.32	3.40
13	.....do	.70	2.13
14	.....do	1.81	3.72
15	Pitt formerly owned by Joseph L. Butcher, Farmingdale	.17	1.85
16	Pit of Hugh Hurley, Farmingdale	.68	1.94
17	Pit of Squankum Marl Co., Farmingdale, now owned by Daniel Mahoney	2.31	4.24
	Average	1.16	2.86

[a] Blair, A. W., The agricultural value of greensand marl: New Jersey Agr. Exper. Sta. Circ. 61, p. 12, 1916.

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[38] Twitchell, M. W., field notes on file at New Jersey Department of Conservation and Development.
[39] Twitchell, M. W., idem.

A sample collected by W. C. Phalen from Daniel Mahoney's property was analyzed in the laboratory of the United States Geological Survey and found to contain 3.54 per cent of potash.[40]

The thicknesses represented by these samples are unknown, but in so far as the samples are representative of the Manasquan marl they show a lower potash content than that of either the Navesink or the Hornerstown and thus confirm the similar findings at holes 17 to 19, localities 96, 97, and 100, near Pemberton. The phosphoric acid content of the Manasquan marl, as judged by these samples, is noteworthy and is probably a considerable factor in its former agricultural popularity.

The Shark River marl (Eocene) is also exposed near Farmingdale at locality 122, along Manasquan River about 1 mile below the Johnson pits, above described. In 1912 Dr. Twitchell[41] measured the following section at this place:

Geologic section on Manasquan River about 1 mile south of station at Farmingdale.

	Feet.
Yellow sand and gravel	4–6
Chocolate-colored clay, more or less weathered, with some thin sand seams at base	3–4
Marl, mottled and indurated	1+
Marl, mottled bluish green, with considerable glauconite and drab clay specks and streaks	6
Water's edge.	
	17

The marl is fossiliferous close to and in the indurated portion. A similar exposure with less marl occurs at locality 123, about 0.1 mile farther up the river.

POPLAR AND ELBERON.

Along the creek about 0.75 mile south of Poplar, in Monmouth County, the old marl pits at locality 124 and vicinity are much overgrown, but on the north side of the creek the upper part of the Manasquan marl is exposed with the base of the Kirkwood. Dr. Kümmel visited this locality in 1917 but found no fresh openings.

At locality 125, about 0.8 mile southwest of the station at Elberon, in Monmouth County, Dr. Twitchell found, in 1912, an exposure of Shark River marl in a gully near the barn of the Deal Golf and Country Club. Beneath 4 feet of yellow sand and gravel he found 8 feet of fairly uniform mottled grayish-green marl with clay specks. There were old marl pits in the vicinity.

The main body of Shark River marl lies about 0.6 mile south of Elberon and occupies an area about 1½ miles long at the coast and

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[40] Ashley, G. H., op. cit., pp. 39, 47.

[41] Twitchell, M. W., field notes on file at New Jersey Department of Conservation and Development.

stretches back 1 to 2 miles from the shore. This area is now largely a residential district with pleasure grounds.

Two wells drilled at South Elberon near the railroad and about half a mile north of the Deal Beach station furnish the following combined record, which is slightly modified from Kümmel's account:[42]

Combined record of two wells at South Elberon (locality 126).

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Sand and gravel	12	12	Cape May (Pleistocene).
Greensand marl	78	90	Manasquan.
Quartz sand with some marl grains	40	130	Vincentown.
Quartz and lime sand with some limerock and numerous shells	70	200	Do.
Greensand marl	100	300	(Hornerstown?)
Red sand, becoming black sand at base	59	359	Redbank (?).
Clay	19	378	Navesink (?).
Sand	31	409	Wenonah (?).
Clay	35	444	Marshalltown (?).
Sand	21	465	(Englishtown?)
More clayey sand	7	472	Do.
Sand	33	505	Do.

The Manasquan marl is unusually thick (78 feet) and has an overburden of 12 feet. The lime sand also is well developed but deeply buried. The top of the Hornerstown lies at a depth of 200 feet and is 100 feet thick. There is some uncertainty about the correlation of the beds in the lower part of the section.

ASBURY PARK.

The records of several wells at Asbury Park have been studied by Woolman [43] and compiled into a single record, which, in simpler form, is presented below:

Record of well at Asbury Park.

[Elevation, 10 feet. Uriah White, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Surface soil	16	16	Recent.
Brownish clay, called rotten stone	64	80	[Kirkwood?]
Light-colored clay; resembles "ash marl" below	13	93	[Shark River?]
Greensand; "blue marl" of Prof. Cook	7	100	
Whitish clay with Foraminifera; "ash marl"	40	140	[Manasquan.]
Clay containing considerable greensand	20	160	
Greensand	20	180	
Clay with considerable greensand	20	200	
Whitish clay with thin layer of bryozoan lime sand	40	240	[Vincentown.]
Greensand with *Terebratula* and *Gryphaea*	40	280	[Hornerstown.]
Black sand with a little water that overflows	7	287	Redbank.
Greensand with some clay on top and *Gryphaea*, *Exogyra*, and *Belemnitella* at the bottom	93	380	[Navesink.]
Gray sand with water	50	430	[Mount Laurel and Wenonah.]
Other strata including a water-bearing stratum at 1,083 feet, which is the one utilized	891	1,321	

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[42] Kümmel, H. B., New Jersey Geol. Survey Ann. Rept. for 1904, p. 269, 1905.

[43] Woolman, Lewis, New Jersey Geol. Survey Ann. Rept. for 1895, pp. 72–73, 1896

Here the Hornerstown marl is 40 feet thick and lies 240 feet below the surface. The Navesink marl is reported as 93 feet thick. The Vincentown contains only a thin layer of lime sand. The greensand member of the Manasquan is 20 feet thick, though the formation as a whole is 100 feet thick.

OCEAN GROVE.

A well at Ocean Grove shows the marl beds at somewhat greater depths and with more variations in thickness. The following record is simplified from that of Woolman.[44]

Record of well at Ocean Grove.

[Elevation, 20 feet. Uriah White, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Surface sands	20	20	Recent.
Brownish clay, called rotten stone	55	75	[Kirkwood?]
Light-colored clay, resembling "ash marl" below	30	105	[Shark River?]
Pure greensand	8	113	
Whitish clay with coccoliths and Foraminifera, the "ash marl" of Prof. Cook.	47	160	[Manasquan.]
Darker clay, much mixed with greensand; greensand layer at 172 to 193 feet.	48	208	
Hard clay with greensand grains through it	19	227	
Clay with much greensand, Bryozoa, echinoid spines, Foraminifera at 261 to 264 feet.	37	264	[Vincentown.]
Grayish greensand, with Foraminifera	20	284	[Hornerstown.]
Greensand with comminuted shell at bottom	16	300	Redbank.
Greensand; shell at 362 feet	81	381	[Navesink.]
Gray sand; comminuted shell	76	457	[Mount Laurel and Wenonah.]
Other strata; water from layer at bottom	677	1,134	

Here the top of the Hornerstown is at a depth of 264 feet. The Hornerstown and Navesink together represent a thickness of 101 feet but are separated by a greensand layer, presumably less glauconitic, 16 feet thick.

SEA GIRT.

The New Jersey coast cuts obliquely across the strike of the Coastal Plain strata in this part of the State, so that a well at Sea Girt, which is 6 or 7 miles nearly south of Asbury Park, strikes the marl beds farther down their dip than wells at either Asbury Park or Ocean Grove. A well at the Beach House furnishes the following record, which is simplified from Woolman's account.[45]

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[44] Woolman, Lewis, op. cit., p. 74.

[45] Idem, p. 76.

Record of well at Beach House, Sea Girt.

[Elevation, 11 feet. Uriah White, driller.]

	Thickness.	Depth.	Formation.
	Feet.	*Feet.*	
Beach or dune sand	10	10	Recent.
Yellowish clay	2	12	
Yellow sand and gravel	13	25	
Solid blue sandy clay	25	50	Post-Pliocene or Pliocene.
Solid blue clay, with streaks of sand and wood	10	60	
Fine white sand	6	66	
Hard rock	4	70	
Sand and shell	9	79	
White sand	47	126	
Brownish clay, with streaks of sand; lignite at 126 to 146 feet	109	235	[Kirkwood.]
Light-colored greenish clay much like ash marl below	25	260	[Shark River?]
Black sand marl, glauconitic; blue marl of Cook	15	275	
Light-green marl, contains Foraminifera at 285 to 306 feet; hard blue stones; ash marl of Cook.	70	345	[Manasquan.]
Black sand marl, glauconitic; green marl of Cook	15	360	
Light greenish-gray clays	40	400	
Gray marl; equivalent to lime sand	50	450	[Vincentown?]
Black marl; equivalent to middle marl bed and red sand	39	489	[Hornerstown and Red bank?]
Sandy marl	81	570	[Navesink.]
Sand, water bearing	50	620	[Mount Laurel and Wenonah.]
Other strata	135	755	

Here the top of the Hornerstown is apparently 450 feet below the surface.

LAKEWOOD.

From specimens and information regarding two wells at Lakewood Woolman [46] compiled a record which is presented below in simpler form.

Record of two wells at Lakewood.

[Elevation, 50 feet; depths, 475 and 612 feet. Uriah White, driller.]

		Depth of samples.	Formation.
		Feet.	
Yellowish sand		43	Beacon Hill (?).
Brownish sandy clay		50	[Kirkwood.]
Brownish sandy clay		75	
Brownish sand, medium coarse		112	
Brownish coarse sandy clay		135	
Sand; considerable [number of] greensand grains		168	[Shark River?]
Light-colored clay		170	[Manasquan.]
Light-colored clay	ash marl	200	
Light-colored sandstone, some greensand, slightly calcareous.		240	
Light-colored clay, with some sand		245	
Sandy clay, darker		270	
Greensand		280	
Greensand		350	
Clay, darker than at 170 feet, etc		355	[Vincentown?]
Greensand		360	
Greensand, with *Terebratula*, etc		370	[Hornerstown and Navesink.]
Greensand		390	
Yellowish-gray sand		450	[Mount Laurel and Wenonah.]
Yellowish-gray sand		460	
Other strata not represented by samples		460–612	

In view of the great thickness of the Vincentown reported in the log of the well at Atlantic City, it seems probable that some of the

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[46] Woolman, Lewis, New Jersey Geol. Survey Ann. Rept. for 1896, p. 148, 1897.

greensand referred above to the Manasquan, which here seems unduly thick, should be ascribed to the Vincentown. The top of the Hornerstown is here at a depth of 370 feet.

ATLANTIC CITY.

A deep well at Atlantic City shows the depth of the marl beds at the easternmost limit of the Coastal Plain, at a point about 45 miles from the outcrop in the direction of the dip. The well was drilled about 1,000 feet out on Young's ocean pier at the foot of Tennessee Avenue. The record as compiled by Woolman [47] is presented below in simpler form.

Record of well at Young's Pier, Atlantic City.

[Elevation of pier, 20 feet. Uriah White, driller.]

	Thickness.	Depth.	Age or formation.
	Feet.	*Feet.*	
Floor of pier to mean tide level	20	20	
(Mean tide level to bottom of water)	(15)	35	
Sands, clays, etc.	237	272	Post-Miocene.
Sands, clays, diatom beds, gravel, greensand, etc., including at 780-860 feet the Atlantic City 800-foot water horizon.	943±	1,215	Tentatively Miocene.
Greensand marl	25	1,240	[Shark River?]
Very hard, tough light and dark slate or ash-colored clays with coccoliths and Foraminifera.	200	1,440	[Probably Manasquan.]
Yellowish calcareous rock, soft or hard; two-thirds consists of nearly equal mixture of greensand and quartz; the other third is carbonate of lime, the cementing material; contains Foraminifera.	460	1,900	[Probably Vincentown.]
Glauconitic greensand marl	40	1,940	[Probably Hornerstown and Navesink.]
Clay mixed with a little greensand	70	2,010	
Indurated ash-colored clay, "hard almost as rock"	60	2,070	
Glauconitic greensand marl similar to that at 1,900 to 1,940 feet.	80	2,150	
Black or dark micaceous sandy clays	156	2,306	[Mount Laurel and Wenonah?]

The top of the Hornerstown marl is here apparently at a depth of 1,900 feet. Two beds of greensand, 40 and 80 feet thick, are separated by 130 feet of clay. The thickness of the overlying Vincentown sand, 460 feet, is the maximum recorded thickness for that formation, which is not, however, so calcareous here as in Salem and Burlington counties.

SUMMARY OF FIELD DATA AND ESTIMATES.

At Sewell three greensand beds of commercial quality and thickness have been recognized, which with some variations are generally distinguishable throughout the region where borings were made. These are gray or bank marl, green marl, and chocolate marl. The following table gives the range in thickness and quality of these three beds at the five localities explored.

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[47] Woolman, Lewis, New Jersey Geol. Survey Ann. Rept. for 1901, pp. 110-114, 1902.

Thickness and potash content of commercial beds of greensand at five localities in Salem, Gloucester, Camden, and Burlington counties.

Locality.	Gray marl.		Green marl.		Chocolate marl.	
	Thickness.	K_2O.	Thickness.	K_2O.	Thickness.	K_2O.
	Ft. in.	*Per cent.*	*Ft. in.*	*Per cent.*	*Ft. in.*	*Per cent.*
Salem	12 4	6.19	9	7.19	[a]2	[a]7.26
Woodstown	12	6.12	11 7	7.58	8 9	6.69
Sewell	8 4	6.09	10 10	7.52	15 5	5.99
Somerdale			9 1	7.35	18	6.32
Elmwood Road	9 7	6.01	12 11	7.26	28 2	6.32
	10 7	[b]6.11	10 8	[b]7.30	14 6	[b]6.29

[a] Not characteristic chocolate marl; may belong with overlying bed.

[b] Average weighted according to the thicknesses of the beds at their respective localities.

The middle bed or green marl is distinctly richer in potash than the other beds, but probably all contain sufficient potash to be considered workable by any process that could utilize the richest bed.

The following table gives a summary for the five districts enumerated of the data regarding the thickness of the marl as a whole and of the amount and value of the contained potash:

Summary of thickness of the Hornerstown and Navesink marls and of estimates of amount and value of the contained potash for five districts ranging northeastward from Salem County, into Burlington County.

	1	2	3	4	5	6	7		8	
District.	Number of holes (includes wells cited).	Average thickness.	Number of Survey borings.	Average thickness at Survey borings.	Average content of K_2O.	Estimated content of potash per acre in 2.5-acre tract.	Value of potash per ton of greensand.[a]		Value of potash per acre of ground.[a]	
							At $2.50 per unit.	At $1.50 per unit.	At $2.50 per unit.	At $1.50 per unit.
		Feet.		*Feet.*	*Per cent.*	*Tons.*				
Salem	9	30	2	20	6.62	3,800	$13.24	$7.94	$760,000	$456,000
Woodstown	12	37	3	32	6.80	6,300	13.60	8.16	1,260,000	756,000
Sewell	44	38	3	34	6.50	6,400	13.00	7.80	1,280,000	768,000
Somerdale	11	41	3	26	6.66	5,200	13.32	7.99	1,040,000	624,000
Marlton	20	49	2	50	6.50	9,400	13.00	7.80	1,880,000	1,128,000
Total or average.	96	40	13	32	6.60	6,790	13.23	7.94	1,353,600	812,100

[a] The values given in columns 7 and 8 have no relation to the present value of the land, for they are dependent upon the successful extraction of the potash by processes of which the success and the cost of installation and operation have not yet been commercially demonstrated.

In column 1 of the above table are included all wells and borings from which measurements were obtained in these five districts. Of the 44 listed under Sewell, 25, made by the West Jersey Marl & Transportation Co. (see p. 51) stopped at the chocolate marl. The record of these holes was supplemented by adding to the average thickness of the bank and green marls the average thickness of the

chocolate marl as determined at holes 8 to 10. The resulting average compares very well with the averages for the adjacent districts.

In column 2 the final average is weighted according to the number of holes and the average thickness at the respective localities.

In column 3 only Survey borings which entered the Hornerstown and Navesink marls are included.

In column 4 the final average is weighted according to the number of holes and the average thickness at the respective localities.

In columns 5 and 6 the final averages are weighted according to the average thickness and potash content of the marl at the respective localities.

In column 7 the final averages are not weighted.

In column 8 the final averages are weighted according to the estimated tonnage per acre at the respective localities.

In the region from Medford to Birmingham and Pemberton seven wells, which show an average thickness of about 45 feet for the combined Hornerstown and Navesink marls, indicate the northeastward continuation of the marl in commercial thickness beyond the region explored by Survey borings.

At Jobstown 56 feet of marl probably referable to the Hornerstown and Navesink is reported. The records of three wells at Wrightstown and New Egypt show great thicknesses of marl, parts of which are probably referable to the Manasquan or Vincentown. They suggest, however, the northeastward continuation of a great body of the Navesink and Hornerstown marls.

Northeast of Sykesville the two beds are separated by the Redbank sand. At Hornerstown a well penetrated 22 feet of green marl and 24 feet of gray marl, probably assignable respectively to the Hornerstown and Navesink. Between these beds lies 15 feet of more or less marly material thought to represent the Redbank. Near Eatontown and at Crawford Hill (locality 119) measurements by Dr. Kümmel indicate a thickness of 20 to 25 feet of Hornerstown marl. Thus it appears that in the region where the Hornerstown and Navesink marls are distinct they tend to maintain thicknesses which if combined would equal or exceed their combined thickness southwest of Sykesville. Each of these beds is present in commercial thickness in Monmouth County.

In Monmouth County the Cream Ridge and Marlboro districts probably afford the most favorable conditions for commercial development of the Navesink marl, and the Hornerstown, Freehold, and Eatontown districts are probably best for the exploitation of the Hornerstown marl.

Comparatively few analyses and no complete measurements of thickness of the Manasquan marl are available, but the data at

hand for localities where it is accessible suggest that the more glauconitic portions of the marl are thinner and contain from 2 to 4 per cent less potash than the averages for the combined Navesink and Hornerstown given in the above table. It is thus probably unsuited for the commercial extraction of potash, but there is no apparent reason why it might not again find favor for direct application as a fertilizer to soils deficient in potash or phosphoric acid.

GENERAL ESTIMATES FOR ENTIRE MARL BELT.

Washington [48] estimates that the greensand beds in New Jersey contain 2,034,000,000 metric tons, equivalent to about 2,243,114,000 short tons of potash. This estimate is based on the assumption of a bed of greensand 6 meters (about 20 feet) thick, containing 6 per cent of potash (K_2O), and occupying a belt 160 kilometers (99.4 miles) long and 16 kilometers (9.9 miles) wide. These assumptions appear to be fully justified, except, perhaps, that for the width of the belt. The marl doubtless underlies all that portion of the State southeast of the line of its outcrop and contains potash throughout its breadth, a much wider area than the 16-kilometer strip. Most of the deposit, however, is inaccessible because of the overburden, which, on account of the geologic structure, increases toward the southeast. In Monmouth County, as previously shown, the part of the marl accessible by open-pit mining occupies an area 10 miles or more wide, though much of this area is also underlain by the Redbank sand. Farther southwest the similarly accessible portion of the belt is much narrower.

In Monmouth County the Navesink and Hornerstown marls are distinct, but for purposes of computation they may be considered together as if occupying a single belt, as they do farther southwest.

The average of 25 measurements, at intervals of 4 miles, across the marl belt as mapped is 2.1 miles. From the table on page 104, an average thickness of 40 feet may be assumed for the combined beds and a potash content of 6.6 per cent. The accessible portion of the greensand mass may thus be considered as a triangular prism 100 miles long, 2.1 miles wide, and 40 feet thick along its southeast border but wedging out along its northwest border. The total potash content of such a prism would be approximately 513,905,000 short tons. Of this quantity part has been removed by stream erosion and part is doubtless so deeply covered by Quaternary deposits that it may not be considered accessible. Thus if one-half is deducted, there remains about 256,953,000 short tons of potash that could be mined by open pits. This figure is probably conservative.

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[48] Washington, H. S., Italian leucite lavas as a source of potash: Met. and Chem. Eng., vol. 18, p. 71, 1918.

The average annual importation of potash (K_2O) for the five years immediately preceding the war, including 1914, was 257,143 short tons. At this rate the New Jersey greensand deposit would furnish enough potash to supply the needs of the United States for nearly 1,000 years, if only the material obtainable by open-pit methods were used.

Should it ever become practicable to use underground methods of mining the available quantity of potash would be enormously increased. Wells southeast of the marl belt and along the shore indicate a thickening of the greensand belts in the direction of the dip. There are, however, no data about the maintenance or change of quality in that direction. The maximum recorded depth of the top of the Hornerstown appears to be 1,900 feet in the well at Atlantic City.

SUMMARY FOR LIME SAND.

The lime sand in probable commercial thickness is exposed or has been recognized in wells as far north as Wrightstown. Northeastward from this place the Vincentown sand becomes predominantly quartzose. The lime sand is reported as 25 feet thick in Salem County, but at the well of the Salem Water Co., at Quinton, it is 108 feet thick, and at Atlantic City 460 feet thick. In the well of William J. Irick, near Vincentown, it is 31 feet thick, and at Woodstown it is 10 feet or more thick. The maximum reported content of carbonate of lime is 84.7 per cent in a sample from Mannington Township, Salem County, but the average of three samples from that township gave only 66 per cent; 80 per cent material is reported from locality 61, west of Clementon, Camden County. No systematic measurements or samples of the lime sand are available. Ordinarily it has considerable overburden and lies a mile or more from available sites for greensand exploitation.

COMMERCIAL DEVELOPMENT.

Although small amounts of potash have been manufactured from New Jersey greensand and marketed, there has been as yet no large-scale commercial operation or production. In 1916 the Waverly Chemical Co., of Camden, N. J., under the direction of Samuel Peacock, was regularly producing from greensand dug near Sewell a small output of hydrated carbonate of potash for the cut-glass industry.[49] No further production by this company has been reported to the Geological Survey.

In the same year [50] the Kaolin Products Corporation was operating a plant at Jones Point, N. Y., on Hudson River about 40 miles

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[49] Gale, H. S., Potash in 1916: U. S. Geol. Survey Mineral Resources, 1916, pt. 2, p. 130, 1917.

[50] Gale, H. S., op. cit.

above New York City. The plant was designed to produce 1 ton of potash a day but was only experimental and not intended for commercial production. The process as at present developed is described below in the account of the Eastern Potash Corporation. In 1917 the company, having changed its name to the American Potash Corporation, continued experimental operations at Jones Point[51] and claimed to have solved the difficulties of extracting potash on a commercial scale from the greensand of New Jersey. Among the proposed by-products were "agricultural lime," brick, tile, and artificial stone. No production of potash was reported by the company during the year.

The Eastern Potash Corporation was subsequently organized to take over the rights and property of the American Potash Corporation in so far as they related to the production of potash and by-products from greensand. This corporation, with offices in New York, continued the experimental work at the Jones Point plant and produced and marketed in 1918 a small quantity of high-grade caustic potash. The company now has under construction near New Brunswick, N. J., a plant designed to treat 1,000 tons of greensand per day. According to a recently published statement[52] the process which this company claims to have demonstrated commercially consists in grinding the greensand in ball mills to 200 mesh, and then digesting the material with milk of lime in an autoclave or a special type of continuous digestor for 30 to 60 minutes with steam at a pressure of 200 pounds. The lime (CaO) should equal the weight of the greensand. The digested material is filtered twice, and a solution containing about 80 per cent of the potash in the charge is evaporated in a multiple-type evaporator from an original strength of about 2 per cent of potash to about 45 per cent.

This solution can be further concentrated to produce the ordinary 90 per cent solid caustic potash.[52a] The excess steam from the digestion and other sources of waste heat from the plant will be utilized for evaporation. For the manufacture of tile or brick the residue is mixed with sand. The hydrous calcium silicate and excess lime hydrate serve as binders, and the product is hardened by steam.

The Atlantic Potash Co. (Inc.),[53] with offices in New York, was organized early in 1917 to produce potash from greensand by a process invented by G. F. von Kolnitz. It has mined a considerable amount of greensand at its pits near Marlton, in Burlington County,

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[51] Gale, H. S., and Hicks, W. B., Potash in 1917: U. S. Geol. Survey Mineral Resources, 1917, pt. 2, p. 440, 1918.

[52] Wells, A. E., The potash industry of the United States and its possibilities for future production: Bur. Mines Minerals Inv., preliminary report, pp. 15–16, August, 1919.

[52a] Shreve, R. M., Potash recovery in New Jersey: Chem. Age, May, 1920. See also later publications by same author: Action of lime on greensand: Jour. Ind. and Eng. Chem., vol. 13, pp. 693–699, August, 1921; Greensand as a source of potash: Chem. and Met. Eng., vol. 25, p. 1056, December 7, 1921.

[53] Gale, H. S., and Hicks, W. B., op. cit.

N. J. (see Pls. II and VIII, *A*), and has marketed a small quantity of high-grade potash extracted therefrom in its experimental plant at Stockertown, Pa. The process consists in preheating the greensand to 350° C., mixing it with calcium chloride, passing the mixture through a furnace at about 850° C., leaching the product, and finally obtaining potassium chloride by evaporation and crystallization. The company had suspended operations by the fall of 1918 but was planning to erect a plant on its ground near Marlton. No further progress has been reported to the Survey.

The large-scale experiments of F. Tschirner at Yorktown[54] in 1917 led to the establishment of the R. S. Ryan Co.'s plant at Reeves station (Pl. IX, *D*), 2 miles north of Medford, in Burlington County, where the company had acquired ground. The plant, which is regarded as only for commercial experiment, handles about 50 tons of greensand and produces from 2 to 3 tons of potassium chloride (KCl) per day. The process consists in grinding greensand and lime sand, taken from the company's pits near the plant, mixing these with salt, and heating the mixture in a rotary kiln. The clinker is leached in water, and the potassium and sodium chlorides are removed by evaporation and crystallization. Most of the sodium chloride is recovered and used over again. Potassium chloride, running 88 to 90 per cent, with a little potassium sulphate, is produced. By March, 1919, the company had sufficiently overcome initial difficulties to start commercial operation. In September of the same year the plant was reported closed. The figures for production are not available.

In the fall of 1918 the newly organized Reduction & Concentration Corporation acquired a factory building and grounds at Gloucester, N. J., for rendering soluble the potash in greensand and making complete fertilizer in which was to be incorporated the treated greensand. Preliminary arrangements were made for utilizing greensand from properties of the Norcross & Edmunds Co. at Birmingham and of the West Jersey Marl & Transportation Co. at Sewell. Installation of machinery and experimental work were said to be in progress from January to March, 1919, when the writer was in the vicinity, but no information as to the process was divulged, and no opportunity was afforded to view the operations. No production and no further activity of the corporation have been reported to the Survey.

In 1918 the Coplay Cement Manufacturing Co., of Coplay, Pa., which had recently installed a Cottrell dust-collecting system and equipment for the extraction of potash from flue dusts, experimented with greensand from Birmingham, N. J., as a constituent of its cement mixture to see if the amount of potash recoverable from

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[54] Gale, H. S., and Hicks, W. B., op. cit.

these dusts could be increased. The company's usual mixture contained about 1 per cent of potash. The greensand employed contained about 7 per cent of potash, so that its use in the proportions selected for the experiments would nearly double the amount of potash available for volatilization. The experiments showed that the potash was largely volatilized, and that the cement, though darker colored on account of the iron in the greensand, was salable under the market conditions then existing. The company next acquired greensand deposits near Kirkwood, in Camden County (locality 60, Pl. II), and began commercial utilization of the greensand. After a few runs, but not from any difficulty arising from the use of greensand, it became necessary to shut down the dust-collecting units of the plant. These were still inactive in October, 1919, but resumption of activity was expected if the potash market seemed favorable.

A number of other processes for the extraction of potash from greensand have been devised and most of them patented. None of these processes, however, has reached so advanced a stage of large-scale experimentation as those above described.[55]

OUTLOOK.

The development of a potash industry based on the New Jersey greensands depends on the ability of the manufacturers to compete not only with foreign producers but also with American producers.

According to Hicks [56] the prices of German potash salts delivered before the war under special contracts for large quantities direct from the source of production to Gulf and Atlantic ports were as follows:

Wholesale prices per short ton of potash salts c. i. f. Atlantic ports, 1911–1914.[a]

Potash salt.	Approximate percentage of potash (K_2O).	1911–1913			1914 [b]			
		List price.	Discount.[c]	Net price.	List price.	Discount.[c]	Net price.	Approximate net price per unit of potash (20 pounds of K_2O).
Sulphate	48.6	$46.30	$6.95	$39.35	$47.58	$7.14	$40.43	$0.83
Muriate	50.0	38.05	5.71	32.34	39.07	5.86	33.21	.66
Manure salts	20.0	13.30	2.06	11.24	13.58	2.10	11.48	.57
Hartsalz	16.0	10.65	1.65	9.00	10.87	1.68	9.19	.57
Kainite	12.4	8.25	1.28	6.97	8.36	1.30	7.06	.57

[a] Federal Trade Commission report on the fertilizer industry, 1916, p. 155.

[b] These prices, which were for January to June, 1914, were increased slightly during the later part of the year. See Oil, Paint, and Drug Reporter, vol. 85, p. 59, 1914.

[c] 15 per cent discount on sulphate and muriate and 15½ per cent on 20 per cent manure salts, hartsalz, and kainite.

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[55] See Gale, H. S., Potash in 1916: U. S. Geol. Survey Mineral Resources, 1916, pt. 2, pp. 126–129, 1917. Gale, H. S., and Hicks, W. B., Potash in 1917: U. S. Geol. Survey Mineral Resources, 1917, pt. 2, pp. 440, 442–446, 1918; also Hicks, W. B., Potash in 1918: U. S. Geol. Survey Mineral Resources, 1918, pt. 2, pp. 385–445, 1920. Each of these papers contains a list of patents and a bibliography.

[56] Hicks, W. B., op. cit., pp. 398–401.

As will be observed from the table, net prices to large importers varied from 57 cents per unit (20 pounds of K_2O) for the lowest-grade product to 83 cents for sulphate. The list prices, which are generally shown in market quotations in the United States, correspond to 67 cents per unit for the low-grade material and 98 cents for sulphate. Ocean freight rates to the United States on these salts in bulk from Hamburg averaged about $2 per metric ton to northern ports and $2.50 to $2.90 to southern ports.

After the embargo of January 30, 1915, placed on the exportation of potash salts from Germany, the prices of these salts rose rapidly. Early in 1915, market quotations on 80 per cent muriate were around $115 a ton and gradually rose to $500 a ton in December. The quotations in 1916 varied from $300 to $490 a ton, in 1917 from $325 to $450 a ton, and in 1918 from $260 to $350 a ton. These quotations are not indicative of the actual selling price of potash materials, as only limited quantities of muriate were on the market and muriate was at a premium because of its use as a raw material in the manufacture of various refined potassium salts. The actual selling price in the eastern markets of the domestic output was about $4.87 per unit in 1916, $4.79 in 1917, and $4.61 in 1918. These data are shown in the following table.

Wholesale price of potash in the United States, 1915–1918.

Year.	Market quotations of 80 per cent muriate.[a]						Approximate average selling price per unit of K_2O of domestic output.	
	Per short ton of salt.			Per unit of K_2O.			F. o. b. plant.	Eastern markets.
	High.	Low.	Average.	High.	Low.	Average.		
1915	$500	$115	$245	$10.00	$2.30	$5.90	$3.14	$3.64
1916	490	300	415	9.80	6.00	8.30	4.37	4.87
1917	450	325	380	9.00	6.50	7.60	4.29	4.79
1918	350	260	315	7.00	5.20	6.30	4.11	4.61

[a] Quotations for 1915 and 1916 taken from Jour. Ind. and Eng. Chemistry and for 1917 and 1918 from Oil, Paint, and Drug Reporter.

When the armistice was signed in November, 1918, only a few large producers in the United States had made their original investments out of the potash industry, many plants had been operated only a short time, and others were under construction. About one-third of the potash produced in 1918 was still in the hands of producers, money for operating expenses had been advanced on the potash held in storage, and developments had gone forward under the prevailing price of $4 to $5 per unit of potash. Anticipation that low-priced potash from foreign sources would be available followed the armistice agreement, checked sales of domestic potash, and caused the price to fall to about $2.50 per unit—a price lower than the cost of production of many producers. These conditions caused a crisis in the potash industry, and producers began to close their plants. By the early part of 1919 nearly all producers had shut down and some had gone out of business.

The cost of production of American salts is summarized by Gale and Hicks[57] as follows:

> Available data on the cost of producing potash from the various American sources are very meager, but if the following estimates of cost production are correct they indicate that undoubtedly some of the large developments will survive. Condra gives the cost of producing potash in the alkali-lake region of Nebraska as between $20 and $44 a short ton, or an average of $30 a short ton of crude salts. This corresponds

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[57] Op. cit., p. 403.

to an average of about $120 a ton of potash ($K_2O$). The conditions as regards labor, fuel, and supplies in this region are very difficult, and the cost should be considerably reduced if such conditions are improved. It has been stated that sulphate of potash can be produced from alunite at Marysvale, Utah, at approximately $20 a ton (equivalent to about $40 a ton of K_2O), and that if an aerial tramway were installed the cost would be reduced 50 per cent. Porter estimates that the present cost of production, exclusive of royalty, depreciation, and similar items, by the Security Cement & Lime Co., Hagerstown, Md., is about $30 a ton of pure potash (K_2O) packed on board cars, and that under normal conditions the price might be reduced 50 per cent. Treanor, from his experiences as manager of the Riverside Portland Cement Co., thinks the cost of saving potash from flue dust may run $100 a ton of K_2O for the first month, may average $40 a ton of K_2O the first year, and that it may ultimately be reduced to less than $20 a ton of K_2O.

Estimates of the cost of American production thus run from $20 to $120 a ton of K_2O or from $0.20 to $1.20 per unit.

Wells[58] in describing the plant of the Eastern Potash Corporation estimates that the cost of producing caustic potash in a plant with a capacity of 1,000 tons of greensand per day, including interest and general plant depreciation, may reasonably be as much as $1.50 per unit of K_2O. Such a plant would produce about 45 to 50 tons of K_2O as caustic potash and would turn out about 2,000,000 brick per day. It should, however, be borne in mind that the cost of raw material for the brick is greater than that for ordinary brick and that the by-product brick, to find a suitable market, must possess some special attractiveness such as color, endurance, or adaptability to particular uses. With the requirement of a specialized market the disposal of so much brick might prove a problem in itself.

It is doubtful if companies making potash their only product in the treatment of greensand can do so for less than the $1.50 per unit estimated for the Eastern Potash Corporation.

The experience of Treanor, cited above, appears to indicate that after the installation of a dust-collecting and potash-refining system in a cement plant potash may be recovered from the dust rather cheaply. Wells,[59] however, thinks that the cost of the high-grade product, allowing for royalties, selling costs, and storage charges, would be nearly $1.80 per unit.

If these figures are at all accurate it is evident that the cost of producing potash from greensand, even in conjunction with cement manufacture, is greater than that of producing it from alunite and some of the western brines. The greensand product has the advantages of proximity to market and of low freight cost.

In view of the present disturbed state of industrial conditions in Germany and of the heavy war taxes it seems certain that the cost

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[58] Wells, A. E., The potash industry of the United States and its possibilities for future production: Bur. Mines Minerals Inv., preliminary report, p. 16, August, 1919.

[59] Idem, p. 7.

of German potash will hereafter greatly exceed and perhaps be as much as double pre-war prices. On the other hand, there is the possibility that in the United States the cost of labor and fuel may have reached its peak and that with the resumption of industries interrupted by the war and with increased production these costs may decline.

The American potash industry thus bids fair to be on a nearly even basis with foreign potash industries. Whether or not greensand may have a place in the American potash industry will depend on how well the greensand operators may be able to compete with western producers.

AVAILABILITY OF POTASH IN GREENSAND.

The scarcity of potash and the high prices of fertilizers during the war led many farmers to think again of greensand as a source of fertilizer. Although accounts of its use in the early reports were highly favorable, the results of more recent local applications were contradictory, and the writer received many inquiries about the availability of the potash in greensand.

From the standpoint of the fertilizer manufacturer the potash is not considered available because of its slight solubility in water. Recent experiments conducted by True and Geise, of the Bureau of Plant Industry, United States Department of Agriculture, show that plants in their early growing stages will assimilate potash from greensand as effectively as from the usual soluble commercial potassium salts. These authors[60] used two sets of carefully controlled pot cultures of wheat and red clover with nutrient solutions. In one set the potash was supplied by the usual commercial salts; in the other set potash was supplied by greensand in proportions such as those formerly employed in agricultural practice, all other sources of potash being excluded. They reached the following conclusions:

> It has been shown by pot experiments carried out with crushed quartz and Shive's culture solution as a basis that greensands and greensand marls from Virginia and New Jersey are able to supply sufficient potassium to satisfy the demand of Turkey Red wheat and red clover during the first two months of their growth. This enables them to make a greater dry weight of tops than was seen in similar cultures in which the potassium demand was supplied by potassium chlorid, potassium sulphate, and potassium phosphate. The prompt availability of sufficient potassium to meet the needs of many, perhaps most, farm crops seems to be indicated.

It is reported that the New Jersey Agricultural Experiment Station has been working on the same problem and has reached similar conclusions.

In a letter to the Director of the United States Geological Survey Dr. True points out that land which already has a sufficient supply

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[60] True, R. H., and Geise, F. W., Experiments on the value of greensand as a source of potassium for plant culture: Jour. Agr. Research, vol. 15, pp. 483-492, Dec. 2, 1918.

of potash and the other ingredients supplied by greensand marl will not be benefited by application of it. This may account in some measure for the contradictory nature of the reported results of its use. Dr. True further states that arrangements have been made for the shipment of three carloads of greensand from deposits near Marlboro, N. J., to the vicinity of Florence, S. C., where it is to be applied to fields known to be deficient in potash. Results of interest and value are to be expected from these experiments.

More recent experiments along a somewhat different line have been carried out by McCall and Smith, of the Maryland Agricultural Experiment Station. These authors[61] composted greensand with sulphur, soil, and manure in varying proportions, taking samples from time to time, extracting these samples with distilled water, and analyzing the water extracts for their acidity and their sulphate and potassium content. Two types of greensand were used, one from Sewell, N. J., containing 5.88 per cent of potassium (K), and the other from Crownsville, Md., containing 1.42 per cent of potassium. Each compost had as a basis 1,500 grams of greensand, 500 grams of commercial flowers of sulphur, and 0, 250, or 500 grams of partly rotted yard manure, aid-dried and ground fine. In some of the tests Collington sandy loam and precipitated calcium carbonate were used, also small percentages of the sulphates of iron and alumina. The following results were obtained:

1. In composts consisting of greensand, manure, and soil in different proportions an appreciable amount of the potassium was made water-soluble through sulphofication.
2. The composts containing the largest proportion of manure developed the highest degree of acidity, oxidized the greatest amount of sulphur, and produced the largest quantity of water-soluble potassium.
3. The composts in which soil was substituted for a part of the manure developed less acidity, oxidized less sulphur, and produced a smaller amount of soluble potassium.
4. When all the manure was replaced by soil, the rate of sulphofication was so slow that at the end of 23 weeks only a very small amount of acidity had developed and very little potassium had been made soluble.
5. When no organic matter was added the amounts of acidity and of soluble sulphates were no greater than might be accounted for by natural oxidation of the sulphur.
6. The addition of small amounts of ferrous and aluminum sulphates failed to stimulate sulphofication.
7. Calcium carbonate added to the sulphur-manure-soil compost produced a stimulating effect during the early part of the period but failed to increase the acidity, soluble sulphates, or potassium above the maximum reached by the corresponding composts in which no calcium carbonate was used.
8. More water-soluble potassium was formed in composts containing the high-potassium greensand, but a larger per cent of the total potassium present was liberated in the composts containing the low-potassium greensand.

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[61] McCall, A. G., and Smith, A. M., Effect of manure-sulphur composts upon the availability of the potassium of greensand: Jour. Agr. Research, vol. 19, pp. 239–256, June, 1920.

9. In the composts containing manure the total amounts of potassium recovered in the water extracts varied from 9.1 per cent to a maximum of 41.3 per cent of the total initial amount present.

10. Our results indicate that the composting of greensand or of soil rich in potassium with sulphur and manure may prove to be a practical and efficient method for obtaining available potassium from comparatively insoluble materials.

In the opinion of the writer part of the benefit derived from the use of marl may be the result of an improved texture produced by the mechanical mixture of the greensand with the soil. For example, a mass of clayey greensand applied and worked into a light sandy soil would produce a more loamy texture besides furnishing potash. On the other hand, similar greensand applied to a stiff clayey soil would tend to emphasize the heaviness of such a soil and might be injurious.

EARLIER VIEWS ON AGRICULTURAL VALUE.

Little was known in the earlier days about potash in greensand marl and its part in the beneficial action of the marl upon crops. On the other hand, the importance of the phosphoric acid and lime as beneficial constituents was strongly urged. For those interested in reverting to the use of marl as a fertilizer it may be well to repeat the conclusions drawn years ago by Cook:[62]

1. That the most valuable marls and those which will best pay the cost of long transportation are those which contain the largest percentage of phosphoric acid.

2. That the most durable marls are those containing carbonate of lime, the more the better.

3. That greensands containing but little of either phosphoric acid or carbonate of lime become active fertilizers when composted with quicklime.

4. That marls which are acid and burning from containing sulphate of iron can be rendered mild in properties and useful as fertilizers by composting with lime.

5. That crops particularly improved by it are all forage crops, grass, clover, etc.: for these the green marl may be spread upon the surface to the amount of from 100 to 400 bushels per acre. The crop is generally doubled and in some cases quadrupled by this application. Other marls must be used in larger quantities, but will produce good results.

Potatoes: For this crop marl seems to be a specific. It does not materially increase the growth of the vines, and the yield is not much greater, but the potatoes are smoother and fairer in the skin and dryer and of better quality when boiled. The marl is put on the potatoes in the hill at planting; if not acid, it is thrown directly on the tuber; if acid, the potato is first covered by earth and the marl thrown on or beside that. From 5 to 30 tons may be used on an acre.

Buckwheat: Most remarkable effects upon this crop are produced by marl. Two and one-half tons, or 50 bushels to the acre, spread on after sowing, have caused an equal amount of buckwheat to grow on land which otherwise was not worth cultivating.

Wheat, rye, oats, and corn are improved by the use of marl, though not with the striking results seen on the crops before mentioned. It is applied as a top dressing on the prepared ground, is spread on the surface before plowing, is worked in the hill or drill, or is composted with barnyard manure and spread on the ground according

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[62] Cook, G. H., Geology of New Jersey, pp. 452–453, 1868.

to the farmer's judgment. From 5 to 30 tons and even more may be used upon an acre.

With any kind of garden or field crop it may be used and will be beneficial both to the crop and soil. It is free from the seeds of weeds, is dry and convenient to handle—all of which recommend it to any snug farmer.

MECHANICAL ANALYSES OF GREENSAND.

NATURE OF INVESTIGATION.

In the course of drilling variations were observed in the texture of the marl and in the relative proportions of the different constituents. Quartz was present in all the samples in greater or less amounts and served as an adulterant, lowering the potash content. The claylike constituents, however, consisted in part at least, of finely divided glauconitic material, so that their presence might or might not mean a reduced potash content. In order to study the different constituents of the marl and their relative proportions in the principal beds of commercial thickness mechanical analyses were undertaken somewhat along the lines of the work of Cook [63] and Ashley.[64] The following investigations were carried out: (1) Wet separation to determine the relative proportions of coarser and finer constituents; (2) magnetic separation of coarser residues to determine the percentage of magnetic materials, chiefly glauconite; (3) sizing the products of the magnetic separation to determine the sizes and shapes of the mineral grains and the relative abundance of grains of certain sizes and shapes; (4) microscopic study of glauconite grains in thin section (for discussion see pp. 139–140); (5) chemical analyses of some of the products of the wet and magnetic separations (discussed below).

PREPARATION OF SAMPLES.

Composite samples, 15 in all, derived from 87 originals, were prepared to represent each bed of commercial thickness at each of the six localities explored. Each sample weighed approximately 100 grams and was made up of weighed portions of all samples taken from the given bed at the given locality, each in proportion to the thickness represented by it. The material was weighed without preliminary drying, but at the end check samples weighing 100 grams were dried under the same conditions to which the composite samples were subjected and reweighed to determine the loss of moisture in drying.

WET SEPARATION.

In a preliminary trial 100 grams of greensand was placed in a beaker, covered with water, stirred briskly one or two minutes with a glass rod, and allowed to settle for a few seconds. The liquid with finer particles in suspension was then decanted. This procedure

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[63] Cook, G. H., Geology of New Jersey, pp. 227-280, 1868.

[64] Ashley, G. H., Notes on the greensand deposits of the United States: U. S. Geol. Survey Bull. 660, p. 30, 1918.

was repeated and continued for an hour and three-quarters. At first the material released by washing was of a brownish color and relatively heavy, settling in a comparatively few minutes. This disappeared after five or six washings, however, and a light yellowish green material was developed, which clouded the solution and appeared without evident diminution at every washing. Comparatively little of this cloudy matter had settled, even after standing over night. A few drops of dialyzed iron, added to the solution at the suggestion of George Steiger, caused the flocculation and precipitation of the fine suspended matter and the clearing of the solution.

A second preliminary trial was made to determine whether the cloudy material above mentioned was present as detached particles in the original sample or whether it was developed from the greensand grains by agitation in washing. About 25 grams of greensand in which claylike material was relatively abundant, was placed in a beaker on a stand under a faucet. The inflow of water was directed by a funnel to the bottom of the beaker. The "clay" was soon washed out and the solution cleared. Some cloudiness of the water was developed, however, when the greensand was agitated with a glass rod. This was done at intervals of a few minutes for a period of nearly four hours, and the cloudiness appeared at each agitation. The clear water was then poured off except about 50 cubic centimeters, in which the greensand was again stirred briskly with a rod. The cloudiness at once reappeared just as abundantly as at the early stages of the washing.

It was concluded that the glauconite grains were yielding fine particles either by mechanical wear of grain on grain or by the flow of water over the grains. Of the two agencies the former is apparently the more effective, because practically no cloudiness appeared during the constant flow of water through the beaker. The test suggests that much of the "clay" that is so abundant in some beds of greensand is really composed of finely comminuted glauconite grains. Its presence in the marl, therefore. does not necessarily imply poorer quality.

In making the separations tabulated below the following procedure was observed. After placing the weighed sample in a beaker somewhat more than enough distilled water to cover it was added. The greensand was then stirred vigorously with a rod for one minute and allowed to settle for 30 seconds, after which the cloudy liquid was decanted to a second beaker. These operations were repeated to a total of 10 times for the first five samples and 15 times for the remaining 10 samples. The washed greensand was then removed to a casserole, dried on a steam bath, and weighed. A few drops of dialyzed iron were added to the cloudy liquid, which was then allowed to settle, after which the clear water was decanted and th

settlings dried and weighed in the same manner. In samples G-2, G-10, G-13, G-14, and G-15 the entire washing waters were dried without flocculation and precipitation by dialyzed iron.

Wet separations of composite samples of greensand from Survey borings.

Locality.	Sample No.	Approximate thickness of bed.	Weight of sample.	Residue from washing.		Material washed out.		Loss of weight in washing and drying.
				Grams.	Per cent (A).	Grams.	Per cent (B).	
		Feet.	*Grams.*					*Grams.*
Salem	G-1	12	100	93.44	95.6	4.25	4.5	2.31
	G-2	11	100	95.07	97.3	2.62	2.7	2.31
Woodstown	G-3	11	100	77.04	79.3	20.07	20.7	2.89
	G-4	11	100	84.73	85.7	14.17	14.3	1.10
	G-5	7	100	86.65	88.8	10.95	11.2	2.40
Sewell	G-6	8	100	51.59	53.4	45.09	46.6	3.32
	G-7	12	100	79.75	81.5	18.05	18.5	2.20
	G-8	13	100	84.34	86.2	13.50	13.9	2.16
Somerdale	G-9	8	100.1	39.47	40.0	59.19	60.0	1.44
	G-10	6	100.12	50.94	52.4	46.20	47.6	2.98
	G-11	14	100.04	69.42	71.2	28.07	28.8	2.25
Elmwood Road	G-12	4	100.04	86.70	88.3	11.49	11.8	1.85
	G-13	18	100.04	94.39	97.3	2.62	2.7	3.03
	G-14	23	100.07	81.52	84.3	15.19	15.6	3.36
Pemberton	G-15	9	100.07	75.24	76.8	22.70	23.2	2.13
Average					[a] 80.5		[a] 19.5	2.38

[a] Average weighted according to the thicknesses of the respective beds.

For the check tests on loss of weight in washing and drying four samples were selected, weighed, dried over night on the steam bath, and reweighed with the following results:

Moisture determinations on samples of greensand.

Locality.	Field No. of sample.[a]	Original weight.	Weight at about 100° C.	Loss in weight.
		Grams.	*Grams.*	*Grams.*
Salem	M-1	100	96.95	3.05
	M-8	100	97.19	2.81
Woodstown	M-12	100	96.85	3.15
	M-16	100	97.49	2.51
Average				2.88

[a] The field numbers are those used in the descriptions of the borings at Salem and Woodstown.

The loss of weight on drying for the four check samples is of the same order individually as for the samples subjected to wet separation, though the average is somewhat higher.

The percentage of fines or "clay" in the greensand at the six localities named ranges from 2.7 to 60 and averages about 19.5.

MAGNETIC SEPARATION.

An interesting characteristic of glauconite is that it is moderately magnetic and may thus be separated from quartz and other nonmagnetic substances by passing the dried greensand through a strongly magnetic field. The residues from washing were presented successively in small quantities close under a glass plate placed

inst the poles of a powerful electromagnet. The glauconite was acted and held to the glass plate so long as the plate was in tact with the poles of the magnet. By lowering the plate the iconite could be dropped into any convenient receptacle. This on was repeated until no further results were shown, and thus y complete separations were obtained.

s tabulated below the numbers of the samples and the beds esented are the same as for the wet separations. Ten-gram pors of each sample were used, and the products of the separations weighed.

Magnetic separation of samples of washed greensand.

Locality.	Sample No.	Weight.	Magnetic portion, chiefly glauconite.		Nonmagnetic portion, chiefly quartz.		Excess or loss after separation.	Glauconite grains in original sample (C×A, p. 118).
			Grams.	Per cent (C).	Grams.	Per cent (D).		
		Grams.					*Gram.*	*Per cent.*
L	G-1A	10	8.87	87.3	1.20	12.7	+0.16	83.5
	G-2A	10	9.45	94.1	.59	5.9	+ .04	91.6
	G-3A	10	8.09	80.4	1.97	19.6	+ .06	63.8
stown	G-4A	10	9.60	96.0	.39	3.9	− .01	82.2
	G-5A	10	9.30	92.5	.75	7.5	+ .05	82.1
l	G-6A	10	8.27	82.3	1.78	17.7	+ .05	43.9
	G-7A	10	9.77	97.0	.30	3.0	+ .07	79.1
	G-8A	10	9.51	94.5	.55	5.5	+ .06	81.5
rdale	G-9A	10	9.32	92.6	.74	7.4	+ .06	37.0
	G-10A	10	9.70	96.6	.34	3.4	+ .04	50.6
	G-11A	10	9.62	96.0	.40	4.0	+ .02	68.4
ood Road	G-12A	10	6.24	62.5	3.75	37.5	− .01	55.2
	G-13A	10	9.50	94.5	.55	5.5	+ .05	91.9
	G-14A	10	9.65	96.0	.40	4.0	+ .05	80.9
erton	G-15A	10	5.27	52.4	4.79	47.6	+ .06	40.2
Average [a]				89.9		11.1		73.1

[a] verages weighted according to thicknesses of beds represented.

he excess after weighing was probably due in part to the moisture en from the humid air by the dried greensand during the operas of separation and weighing. The percentage of magnetic terials, chiefly glauconite, in the washed greensand is generally h, being more than 90 in 10 of the 15 samples and averaging 89.9 all the beds represented. The percentage of glauconite grains he unmodified greensand is shown for each bed at each locality he last column of the table. The final average shows 73 per cent lauconite for the entire thickness of the greensand examined at h of the six localities. This figure does not include the finely ided glauconitic material occurring in the greensand as mud or ay" (B in the table on p. 118). No mechanical separation of this d was attempted, but the chemical analyses on page 125 indicate t it is probably highly glauconitic.

SIZE OF GRAINS.

oth products of the magnetic separation (C and D of the table) e passed successively through a series of sieves having 20, 40, 60,

80, and 100 meshes to the inch. The entire magnetic or nonmagn portion of each sample was used, so that the initial weights for sizing operations were assumed to be the same as those of the s arated portions shown in the table. The grains held on each si and in the receiver below the lowest sieve were weighed. From tl weights the percentage of material of the different sizes in e sample were determined as shown in the following table:

Size of grains of glauconite, quartz, etc., in washed greensand.

Locality.	Sample No.	Glauconite, etc. (C).				Quartz, etc. (D).			
		Quantity in sample (grams).	Quantity held on sieves.			Quantity in sample (grams).	Quantity held on sie		
			Mesh.	Grams.	Per cent.		Mesh.	Grams.	Per
Salem.............	G-1A...	8.87	20	0.30	3.4	1.29	20	0.16	
			40	4.80	54.2		40	.47	
			60	2.85	32.2		60	.45	
			80	.59	6.7		80	.17	
			100	.29	3.3		100	.09	
			100+	.03	.3		100+	.02	
				8.86	100.1			1.36	
Do............	G-2A...	9.45	20	.60	6.3	.50	20	.12	
			40	4.73	49.4		40	.17	
			60	2.90	30.3		60	.15	
			80	.79	8.2		80	.09	
			100	.45	4.7		100	.07	
			100+	.11	1.1		100+	.04	
				9.58	100.0			.64	
Woodstown.......	G-3A...	8.09	20	.35	4.3	1.97	20	.20	
			40	3.06	37.2		40	.29	
			60	2.49	30.3		60	.67	
			80	.94	11.4		80	.32	
			100	.75	9.1		100	.30	
			100+	.64	7.7		100+	.25	
				8.23	100.0			2.03	
Do............	G-4A...	9.60	20	.19	1.9	.39	20	.03	
			40	3.77	39.1		40	.07	
			60	3.53	36.6		60	.11	
			80	1.00	10.4		80	.06	
			100	.69	7.2		100	.07	
			100+	.46	4.8		100+	.08	
				9.64	100.0			.42	
Do............	G-5A...	9.30	20	.34	3.6	.75	20	.08	
			40	4.55	48.6		40	.16	
			60	2.90	30.9		60	.27	
			80	.82	8.8		80	.10	
			100	.57	6.1		100	.10	
			100+	.19	2.0		100+	.09	
				9.37	100.0			.80	
Sewell.............	G-6A...	8.27	20	.37	4.4	1.78	20	.08	
			40	2.27	27.1		40	.16	
			60	3.10	37.0		60	.48	
			80	1.04	12.4		80	.35	
			100	.95	11.3		100	.49	
			100+	.65	7.8		100+	.26	
				8.38	100.0			1.82	
Do............	G-7A...	9.77	20	.09	.9	.30	20	.04	
			40	3.25	33.0		40	.06	
			60	4.02	40.9		60	.09	
			80	1.05	10.7		80	.04	
			100	.80	8.1		100	.05	
			100+	.63	6.4		100+	.10	
				9.84	100.0			.38	

Size of grains of glauconite, quartz, etc., in washed greensand—Continued.

cality.	Sample No.	Glauconite, etc. (C).				Quartz, etc. (D).			
		Quantity in sample (grams).	Quantity held on sieves.			Quantity in sample (grams).	Quantity held on sieves.		
			Mesh.	Grams.	Per cent.		Mesh.	Grams.	Per cent.
....	G-8A...	9.51	20	0.25	2.6	0.55	20	0.14	24.1
			40	4.72	49.6		40	.24	41.4
			60	3.14	32.9		60	.14	24.1
			80	.71	7.5		80	.02	3.4
			100	.47	4.9		100	.02	3.4
			100+	.23	2.4		100+	.02	3.4
				9.52	99.9			.58	99.8
dale.........	G-9A...	9.32	20	.01	.1	.74	20	.04	5.5
			40	1.21	13.0		40	.09	12.5
			60	2.85	30.8		60	.08	11.1
			80	1.42	15.4		80	.04	5.5
			100	1.45	15.7		100	.07	9.7
			100+	2.30	24.9		100+	.40	55.5
				9.24	99.9			.72	99.8
o............	G-10A..	9.70	20	.17	1.8	.34	20	.05	14.7
			40	3.32	34.2		40	.12	35.3
			60	4.00	41.2		60	.07	20.6
			80	1.07	11.0		80	.02	5.9
			100	.78	8.0		100	.04	11.8
			100+	.37	3.8		100+	.04	11.8
				9.71	100.0			.34	100.1
Do............	G-11A..	9.62	20	.05	.5	.40	20	.01	2.6
			40	2.87	30.1		40	.05	12.8
			60	3.22	33.8		60	.03	7.7
			80	1.05	11.0		80	.02	5.1
			100	.97	10.2		100	.02	5.1
			100+	1.38	14.5		100+	.26	66.6
				9.54	100.1			.39	99.9
wood Road...	G-12A..	6.24	20	.55	8.9	3.75	20	.04	1.1
			40	2.33	37.6		40	.25	6.7
			60	1.69	27.3		60	1.17	31.5
			80	.67	10.8		80	.86	23.2
			100	.53	8.6		100	1.04	28.0
			100+	.42	6.8		100+	.35	9.4
				6.19	100.0			3.71	99.9
Do............	G-13A..	9.50	20	.50	5.3	.55	20	.19	32.2
			40	5.42	57.4		40	.14	23.7
			60	2.97	31.4		60	.15	25.4
			80	.39	4.1		80	.05	8.5
			100	.15	1.6		100	.04	6.8
			100+	.02	.2		100+	.02	3.4
				9.45	100.0			.59	100.0
Do............	G-14A..	9.65	20	.07	.7	.40	20	.10	25.6
			40	6.12	63.0		40	.04	10.2
			60	2.50	26.0		60	.01	2.6
			80	.46	4.7		80	.02	5.1
			100	.27	2.8		100	.02	5.1
			100+	.29	3.0		100+	.20	51.3
				9.71	100.2			.39	99.9
mberton........	G-15A..	5.27	20	.09	1.7	4.79	20	.18	3.9
			40	1.22	23.0		40	.74	15.4
			60	1.69	32.1		60	.66	13.8
			80	.87	16.4		80	.72	15.0
			100	.80	15.1		100	.95	19.6
			100+	.62	11.7		100+	1.55	32.3
				5.29	100.0			4.80	100.0

The glauconite particles range in diameter from more than 20-mesh to less than 100-mesh, but the greatest number by weight fall between 20 and 40 mesh, though many fall between 40 and 60 mesh. Below the last size the quantity of glauconite falls off rapidly, though a few samples, especially G–9A, have considerable material of the smaller sizes.

The quartz grains, too, fall chiefly between 20 and 60 mesh, but there is a large percentage also of the finest grains.

SHAPES OF GRAINS.

The largest glauconite grains, 20-mesh or more in diameter, show their form most clearly. Under the hand lens they appear irregular, botryoidal, or mammillary in general form, suggesting aggregates of rounded grains, rather than casts of foraminiferal shells, though some grains suggest such form. Many appear to be rounded nodules with irregular cracks of lighter color. The grains in general have a shiny surface and dark-green color. The 40 and 60 mesh grains show similar forms and markings but a greater degree of regularity, as if reduced by wear from larger grains. Some of the grains are elongate or curved and have a platy structure or cleavage. The smaller grains are subangular to rounded, though retaining to some extent the suggestion of earlier form and markings. They have evidently been much worn and represent, at least in part, material that has been transported and redeposited. Other grains, nonmagnetic, have seedlike or capsule form and measure 40 mesh or less. These, tested qualitatively, give a strong reaction for phosphate. Typical glauconite grains, somewhat magnified, are shown in Plate IV (p. 6).

The quartz grains are generally irregular, angular, or subangular, though some of the larger grains (40 to 20 mesh) are rounded.

SUMMARY.

Composite samples, so prepared as to represent the principal beds of commercial thickness at each of the localities drilled, were washed, and the residues were magnetically separated and sized. Some greensand was relatively free from clay or mud, but on the average it contained about 20 per cent of such material. Glauconite grains form nearly 92 per cent of two of the beds, but the general average is 73 per cent for the beds examined. The most common size for the glauconite grains is from 20 to 60 mesh. Their shapes are generally irregular and suggest mechanical aggregation.

CHEMICAL ANALYSES OF GREENSAND.

CHARACTER AND NUMBER OF ANALYSES.

The character and number of analyses and determinations made in the chemical laboratory of the United States Geological Survey in connection with the present investigation are shown below. The

potash determinations were all made by the method described by Hicks and Bailey.[65]

Analyses and determinations of greensand, etc.

Character of work.	Number of determinations.
Total K_2O in individual original samples	128
Total K_2O in combined or prepared samples	17
Water soluble K_2O in original samples	18
CaO in individual or combined samples	15
P_2O_5 in individual or combined samples	13
CO_2 in individual samples	2
Moisture determinations	6
Density determinations	3
Analyses of three samples of water, five determinations each	15
Complete analyses of ten samples, eleven determinations each	110
	327

The total potash content of the individual original samples has been given in the logs of the respective borings. It has furnished the basis of the computations and estimates already presented. The density and moisture content of the greensand have also been utilized in these computations and estimates. Some reference has also been made to the determinations of CaO, P_2O_5, and CO_2. Other features of the investigation are described below.

COMPOSITION OF GREENSAND.

Numerous analyses of greensand samples from different parts of New Jersey are given by Cook.[66] Four of them, which relate to localities near those sampled in the present investigation, are given in the following table:

Analyses of greensand.

	1	2	3	4
Phosphoric acid	1.68	1.02	2.69	2.34
Sulphuric acid	.96	.27	.26	.21
Silicic acid	55.93	50.23	49.40	50.00
Potash	5.80	6.32	6.31	6.18
Lime	1.64	1.40	2.52	1.57
Magnesia	1.01	3.45	3.25	.60
Oxide of iron and alumina	24.41	....	....	....
Alumina	....	7.94	8.90	6.15
Oxides of iron	....	20.14	18.66	24.32
Water	8.84	9.00	7.55	6.88
	100.27	99.77	99.54	98.25

1. "Upper marl bed" (Manasquan) from Joshua Forsyth's place near Pemberton; green marl, an average specimen. Cook, G. H., op. cit., p. 435.
2. "Middle marl bed" (Hornerstown), from the Pemberton Marl Co., sent by J. C. Gaskill as an average. Idem, p. 434.
3. "Middle marl bed" (Hornerstown), from pits of West Jersey Marl & Transportation Co.; average of the whole bed dug. Idem, p. 437.
4. "Lower marl bed" (probably Hornerstown rather than Navesink) from farm of Jesse Lippincott, near Oldman's Creek, Gloucester County; and average of the green marl of this neighborhood. Idem, p. 429.

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[65] Hicks, W. B., and Bailey, R. K., Methods of analysis of greensand: U. S. Geol. Survey Bull. 660, pp. [illegible], 1918.

[66] Cook, G. H., The geology of New Jersey, pp. 417-441, 1868.

Much time has elapsed since the publication of Cook's work, and there have been changes in methods of analysis, so that it was thought desirable as a check to make a few complete analyses of greensand samples taken in the present investigation. Four samples were accordingly selected, the analyses of which are given in the following table:

Analyses of greensand.

[R. K. Bailey, analyst. For organic matter see p. 130.]

	M-119	M-99	M-52	M-15		M-119	M-99	M-52	M-15
SiO_2	68.90	50.74	51.83	50.32	Na_2O	0.82	1.53	0.76	0.22
Fe_2O_3	8.91	17.36	17.15	18.38	CO_2	1.00	.88	.36	.15
FeO	1.52	3.34	2.93	3.02	P_2O_5	1.05	1.79	.31	.34
Al_2O_3	3.52	1.93	6.23	7.53	H_2O	7.68	9.08	9.98	8.58
CaO	2.10	2.86	.52	.65					
MgO	1.90	3.76	3.66	3.82		100.96	99.95	100.12	100.89
K_2O	3.56	6.68	6.60	7.88					
			37.92						

M-119. Manasquan marl from hole 17, locality 96, between Birmingham and Pemberton. (See p. 86.)
M-99. Hornerstown marl from hole 15, locality 62, Elmwood Road. (See p. 70.)
M-52. Hornerstown marl from hole 10, locality 85, Sewell. (See p. 49.)
M-15. Hornerstown marl from hole 6, locality 13, Woodstown. (See p. 32.)

Although the localities from which the Cook samples were taken are not definitely known the respective materials represented by the two sets of analyses may perhaps be regarded as fairly comparable. Certain differences, however, deserve mention.

The potash content of Cook's samples 2, 3, and 4 seems at first sight to agree fairly well with that of samples M-99, M-52 and M-15, though it is somewhat lower. It does not appear, however, that Na_2O was separately determined in the Cook samples. This substance is therefore probably included in the figure for potash. Further, as pointed out by Hicks and Bailey,[67] the methods employed in the analyses cited by Cook would tend to give too low a value for the potash. Thus the semblance of agreement in potash content in the two sets of analyses is accidental.

The silica content of the six samples cited in the preceding paragraph is fairly accordant, as is also the content of the combined oxides of iron. The other constituents show a greater degree of variation.

Sample 1 of the Cook set and sample M-119, both of which represent Manasquan marl, show considerably less potash than the other samples, though sample 1 is apparently of better grade than sample M-119, as shown by its lower content of silica as well as by its higher indicated content of potash. The high silica content of both these samples is probably due to a greater admixture of quartz grains in the marl.

The percentages of CaO, P_2O_5, and CO_2 indicate that only small quantities of the carbonate and phosphate of lime are present in the

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[67] Hicks, W. B., and Bailey, R. K., op. cit., p. 52.

better-grade marls. Some of the P_2O_5 is doubtless combined with iron instead of with lime, for the mineral vivianite occurs at a number of the localities sampled.

Some of the iron is probably present in the form of sulphides or sulphates, as indicated by the sulphuric acid of the Cook samples and by the "irony water" noted at many wells.

COMPOSITION OF PRODUCTS OF WET SEPARATION.

In the section on mechanical analyses of greensand (p. 117) it is suggested that much of the claylike material so abundant in some beds of greensand is really composed of finely comminuted glauconite grains. Four analyses were therefore made for the purpose of comparing the chemical composition of the products of wet separation and of unaltered greensand. The samples used were some of those prepared for mechanical analysis. (See p. 118.) Each represents high-grade Hornerstown marl. The chemical analyses are given in the following table:

Composition of products of wet separation.

[R. K. Bailey, analyst.]

	G-7A (coarse residue, Sewell).	G-7B (fine washings, Sewell).	G-13A (coarse residue, Elmwood Road).	G-13B (fine washings, Elmwood Road).		G-7A (coarse residue, Sewell).	G-7B (fine washings, Sewell).	G-13A (coarse residue, Elmwood Road).	G-13B (fine washings, Elmwood Road).
SiO_2	50.38	49.30	49.50	43.70	Na_2O	0.30	0.36	0.26	1.15
Fe_2O_3	18.60	16.33	18.27	15.50	CO_2	.10	2.48	.30	4.04
FeO	2.84	2.61	3.03	2.54	P_2O_5	.28	.64	1.09	[a]
Al_2O_3	7.83	8.92	6.52	11.10	H_2O	8.70	9.22	8.98	10.80
CaO	.37	.72	1.77	3.43					
MgO	3.54	3.44	3.78	2.99		100.88	100.76	100.87	100.98
K_2O	7.85	6.74	7.37	5.73					

[a] No material left for determination of P_2O_5.

These analyses appear to justify the view that the fine or claylike constituents of the greensand marl have practically the same composition as the coarser constituents and that much of the fine material is finely comminuted or amorphous glauconite. When these samples are compared with each other or with samples M-99, M-52, and M-15 of the previous table certain variations appear, but the quantities of the respective constituents are of the same order.

POTASH CONTENT OF THE FINES.

Although it was impracticable to make extended analyses of all the samples of fines obtained by washing (see p. 118), the potash content of each was determined because of its possible bearing on the treatment of the marl in commercial operations. If the fines should prove decidedly lower in potash content than either the

coarser residues or the unaltered marl it might pay to wash the marl before extracting the potash. In the preceding table the potash content of the fines is compared with that of the coarser residues. In the following table the potash content of the fines is compared with the average potash content of the unaltered greensand. (See p. 104.) The discrepancy in thicknesses given for the beds in the two tables cited is due to a revision of stratigraphic data after the mechanical analyses were completed. The beds from which the fines were taken correspond in a general way, however, to those for which the average potash content is given.

Potash content of fines and of unaltered greensand in per cent.

[R. K. Bailey, analyst.]

Locality.	Gray marl.			Green marl.			Chocolate marl.		
	Unaltered.	Fines.		Unaltered.	Fines.		Unaltered.	Fines.	
	K_2O.	Sample No.	K_2O.	K_2O.	Sample No.	K_2O.	K_2O.	Sample No.	K_2O.
Salem	6.19	G-1B	4.73	7.19	G-2B	6.47	....	....	....
Woodstown	6.12	G-3B	5.27	7.58	G-4B	7.04	6.69	G-5B	5.16
Sewell	6.09	G-6B	6.20	7.52	G-7B	6.74	5.99	G-8B	4.81
Somerdale	....	G-9B	6.23	7.35	G-10B	7.26	6.32	G-11B	5.50
Elmwood Road	6.01	G-12B	4.55	7.26	G-13B	5.73	6.32	G-14B	3.14

For the Manasquan marl in the Birmingham-Pemberton area the average of samples M-119, 121, 123, 124, and 125, weighted according to the thickness represented by each sample, was 3.7 per cent of potash, and the fines (sample G-15B) showed 2.89 per cent.

In general the potash content of the fines, as shown in the above table, runs from about 0.1 to 1.5 per cent lower than in the unaltered greensand. At Sewell the fines of the gray marl contain 0.11 per cent more potash than the unaltered marl, but at Elmwood Road the fines of the chocolate marl contain 3.18 per cent less potash than the unaltered marl. As indicated in the table on page 118, the fines of representative samples from all the districts examined average 19.5 per cent of the unaltered marl.

Concentration of the marl by washing would undoubtedly increase the proportion of potash in the resulting residues. This gain would be offset, however, by a loss of potash in the fines so nearly equal that the expense of washing the material would not be justified.

COMPOSITION OF GLAUCONITE.

Cayeux [68] cites a group of analyses showing the chemical composition of actual glauconite. The samples analyzed were all of recent material, mostly taken by the *Challenger* expedition. The analyses are presented in the following table.

Chemical composition of recent glauconite.

	1.	2	3	4	5	6	7
SiO_2	56.62	50.85	51.80	55.17	27.74	46.90	47.46
Al_2O_3	12.54	8.92	8.67	8.12	13.02	4.06	1.53
Fe_2O_3	15.63	24.40	24.21	21.59	39.93	27.09	30.83
FeO	1.18	1.66	1.54	1.95	1.76	3.60	3.10
CaO	1.69	1.26	1.27	1.34	1.19	.20	....
MgO	2.49	3.13	3.04	2.83	4.62	.70	2.41
K_2O	2.52	4.21	3.86	3.36	0.95	6.16	7.76
Na_2O	.90	.25	.25	.27	0.62	1.28	....
H_2O	6.84	5.55	5.68	5.76	10.85	9.25	7.00
	100.41	100.23	100.32	100.39	100.68	99.24	100.09

1–5. From *Challenger* reports.
6. Agulhas Bank, Indian Ocean. Gümbel, C. W., K. bayer. Akad. Wiss. Sitzungsber., vol. 16, p. 417, 1886.
7. Material from *Challenger* office, described by L. W. Collet (Les dépôts marins: Encyclopédie scientifique, p. 167, Paris, 1908) as "the purest specimen of actual glauconite which has ever been found."

The noteworthy features of these analyses are the relatively high percentage of ferric iron as compared with ferrous iron, the relatively high alumina content, and the low or moderate potash content.

Cayeux also cites a list of 23 analyses of glauconite from older sedimentary formations and shows, following other investigators, that these older glauconites, though still ferric, have greater percentages of ferrous iron than the recent types. The analyses also show a considerable increase in the amount of potash and in some at least a diminution in the amount of alumina. Collet [69] remarks that "the glauconite which is forming to-day on the bottom of the sea is not the glauconite of sedimentary rocks, which certainly has undergone transformations that must be studied to understand the genesis of this interesting mineral." These transformations doubtless include the continuation of the process that he terms "glauconitization," to which further reference is made on page 140.

A group of analyses of glauconite from sedimentary rocks, some of which are identical with those given by Cayeux, are cited by

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[68] Cayeux, Lucien, Introduction à l'étude pétrographique des roches sédimentaires: Mém. carte géol. France, pp. 242–244, Paris, 1916.

[69] Collet, L. W., op. cit., p. 168.

Dana.[70] Some of these, together with analyses of material collected in the present investigation, are given in the following table:

Chemical composition of glauconite from older sedimentary deposits.

	1	2	3	4	5	6	7	G-7C[a]	G-13C[a]
SiO_2	49.42	51.24	49.76	50.62	50.42	46.91	49.09	50.58	49.47
Fe_2O_3	16.01	13.44	16.00	21.03	19.90	23.06	10.56	19.50	19.46
FeO	3.00	3.06	3.77	6.02	5.96	2.64	3.06	2.96	3.36
Al_2O_3	10.23	12.22	8.18	3.80	4.79	7.04	15.21	6.72	5.59
CaO	.31	.10	.41	[b] .54	3.21	2.95	.55	.34	.60
MgO	3.78	3.93	3.97	[b] .57	2.28	4.40	2.65	4.10	3.96
K_2O	7.91	7.50	7.57	7.14	7.87	7.31	6.05	8.26	8.04
Na_2O	.26	.31	.52	....	.21	.91	1.21	.04	.16
CO_2	....	....	....	....	....	....	....	.30	.56
P_2O_5	....	....	....	....	....	....	....	.27	1.06
H_2O	8.08	8.20	9.82	9.14	5.28	4.71	11.64	7.76	8.54
Insoluble material	.80	....	....	....	....	....	....	....	....
	99.80	100.00	100.00	99.86	99.92	99.93	100.02	100.83	100.80

[a] For organic matter see p. 130.
[b] Carbonates.
1. Swir River, Russia. Kupffer, A., Jahresb. Chemie, 1870, p. 1307.
2. Ontika, Russia. Kupffer, A., idem.
3. Grodno Valley, Russia. Kupffer, A., idem.
4. Havre, France. Haushofer, K., Jour. prakt. Chemie, vol. 102, p. 38, 1866.
5. Antwerp, Belgium. Dewalque, F., Soc. géol. Belgique Annales, vol. 2, p. 3, 1875.
6. Gozzo Island, Mediterranean Sea. Bamberger, E., Min. pet. Mitt., 1877, p. 271.
7. Ashgrove, near Elgin, Scotland. Heddle, M. F., Roy. Soc. Edinburgh Trans., vol. 29, p. 79, 1879.
G-7C. Sewell, N. J., Hornerstown marl, glauconite grains separated magnetically from the residues of washed greensand. (See pp. 118-119.)
G-13C. Elmwood Road, N. J., Hornerstown marl, glauconite grains separated magnetically from the residues of washed greensand. (See pp. 118-119.)

The magnetic separation in the last two samples was very clear, so that these samples represent material as nearly pure as it seems possible to get by the method given. The potash content is distinctly higher than that of the other samples cited and is probably as high as could be expected from most New Jersey material. These analyses may therefore serve as a further check on the analyses of material from Eatontown given on page 97. By comparison with the unaltered green marl from Sewell and from Elmwood Road (see p. 104), from which these samples were respectively derived, it appears that by washing and magnetic separation the potash content of the concentrate thus formed was increased about 0.7 per cent.

The above table shows the general range and variety of composition of the older glauconites. By comparison of these analyses with those of greensand given above and with the potash content of the samples taken in the several borings it will be seen that much of the New Jersey greensand is very nearly pure glauconite. Further discussion of the nature and origin of glauconite is given on pages 138–142.

WATER-SOLUBLE POTASH.

As the water solubility of potash in greensand has an important bearing on the use of that material as fertilizer or as an ingredient of prepared fertilizers, a number of analyses were made to determine

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[70] Dana, J. D. and E. S., System of mineralogy, 6th ed., p. 463, 1892.

the amount of soluble potash in selected representative samples. The method employed was that given in Bulletin 107 of the Association of Official Agricultural Chemists. The following table shows both the total potash and the water-soluble potash of the samples:

Total and water-soluble potash in greensand.

[R. K. Bailey and E. T. Erickson, analysts.]

Sample No.	Locality.	K_2O (per cent).	
		Total.	Soluble.
M-6	Hole 3, Salem	7.72	0.08
M-15	Hole 6, Woodstown	7.88	.04
M-37a	Hole 8, Sewell	7.62	Trace.
M-38a	.....do	6.18	Trace.
M-65	Hole 11, Somerdale	7.58	.02
M-75	Hole 12, Somerdale	7.32	.02
M-99	Hole 15, Elmwood Road	6.68	.04
M-116	Hole 16, Elmwood Road	6.36	.06
M-119	Hole 17, near Birmingham	3.61	Faint trace.
M-119a	.....do	3.63	Trace.
M-120	Hole 18, near Birmingham	3.27	None.
M-121	.....do	2.75	None.
M-122	.....do	1.83	None.
M-123	Hole 19 near Pemberton	4.29	Trace.
M-124	.....do	2.99	Trace.
M-125	.....do	4.61	Trace.
M-126	Locality 60, near Osage Station	7.17	Trace.
M-127	Locality 118, near Eatontown	7.09	Trace.

From the above table it appears that the water-soluble potash content of greensand is very low. The greensand is thus generally regarded as unsuited for use in prepared fertilizers, though some of it has been used in fertilizer as a filler.

ACID SOLUBILITY.

No special tests of the solubility of greensand in acids were made, but greensand is said to be directly and slowly soluble in dilute acids (sulphuric, hydrochloric, or even acetic), so that the potash becomes available.

SOLUBILITY AND AVAILABILITY.

Although the availability of fertilizer ingredients is generally supposed to depend on their solubility, greensand appears to offer an exception to this rule. Its wide and beneficial use as a fertilizer in former years lends strong probability to the idea that its potash, though practically insoluble in water, is actually available for plant growth. Possibly the weak acids present in some soils or the local reaction between the greensand and the root activity of certain plants may bring about this condition. Experiments of True and Geise, of the United States Department of Agriculture, on the availability of potash in greensand have been described on pages 113–115.

ORGANIC MATTER.

In the analyses reported on pages 124 and 128 organic matter was inadvertently omitted. For the sake of completeness this was later determined for the four samples of greensand and for two of the magnetically separated samples of glauconite. In the determinations, which were made by E. T. Erickson in the laboratory of the United States Geological Survey, the sample was treated initially with dilute sulphuric acid with some boiling to eliminate inorganic carbon dioxide. Possibly a slight and negligible amount of organic matter escaped in this treatment. The residue was then heated nearly to the boiling point of an aggregate of about 50 per cent H_2SO_4 and 10 per cent Cr_2O_3. The following determinations of organic carbon were calculated from the carbon dioxide recovered from this procedure:

Organic carbon in samples of greensand and glauconite from New Jersey.

	Per cent.
Greensand:	
M-15	0.07
M-52	.24
M-99	.10
M-119	.21
Glauconite:	
G-7C	.10
G-13C	.09

Mr. Erickson states that for stabilized organic matter—that is, organic matter not of recent origin—the hydrogen content may be considered as considerably less than the corresponding amounts of carbon and very likely not over one-fifth of that of the organic carbon. The total organic matter for each sample is therefore, roughly, not much greater than the quantity of carbon indicated for it—probably not more than one-fifth greater.

It is worthy of note that for two of the greensand samples the quantity of organic matter present is practically identical with that of the two samples of pure glauconite and that for the other two samples of greensand the quantity of organic matter is still very small.

The bearing of organic matter upon the formation of glauconite is discussed on pages 140–141.

PHOSPHORIC ACID AND LIME.

As the investigation dealt chiefly with potash, little attention was devoted to phosphoric acid and lime, but some analyses were made as a check on earlier determinations and because of the agricultural

importance of these substances in the marl. Cook[71] emphasized the importance of the phosphoric acid in these words:

> Phosphoric acid is the most valuable constituent of the whole. Indeed, it may be asserted as a general truth, that the greensand marls may be valued just in proportion to the percentage of this acid they contain.

In that day the effect of potash on plant growth was just beginning to be realized. In the light of the experiments of True and Geise it now seems probable that the potash in the marl is sufficiently available to have agricultural importance at least equal to that of the phosphoric acid.

The average phosphoric acid content of New Jersey greensand marls as shown by 130 analyses given by Cook[72] is 1.78 per cent. Similarly the average lime content derived from 105 of Cook's analyses is 2.25 per cent. The highest individual percentage of phosphoric acid cited by him was 6.87 in a sample from the upper marl (Manasquan) from Poplar. The highest percentage of lime (not counting that reported as carbonate) was 15.19 in a sample from the lower bed (Navesink) from Holmdel.

Fairly recent analyses cited on pages 95, 96, and 98 give 0.907 per cent of phosphoric acid as the average of ten samples of Navesink marl from the Marlboro district, 0.96 per cent as the average of three samples of Hornerstown marl from Freehold, and 1.16 per cent as the average of seven samples of Manasquan marl from Farmingdale.

Analyses of three composite samples of Manasquan marl from the Birmingham-Pemberton district, made in connection with the present investigation and given on page 88, show from 1.37 to 3.58 per cent of phosphoric acid and from 1.53 to 3.86 per cent of lime. Additional analyses of selected individual or composite samples from the Hornerstown and Navesink marls are given in the following table:

Lime and phosphoric acid in selected samples of marl.

[R. K. Bailey and E. T. Erickson, analysts.]

Sample No.	Locality.	Formation.	CaO	P_2O_5
			Per cent.	*Per cent.*
M-7	Hole 3, Salem	Hornerstown	2.97	0.68
M-15-16-17[a]	Hole 6, Woodstown	do	.60	.25
M-43	Hole 9, Sewell	do	.07	Trace.
M-52	Hole 10, Sewell	do	.52	.31
M-62	West Jersey Marl & Transportation Co.'s pit, Sewell	Navesink(?)	.20	Trace.
M-63	do	Hornerstown	1.49	.38
M-75	Hole 12, Somerdale	do	.17	.17
M-78-79[b]	do	Navesink(?)	.08	.15
M-89	Hole 15, Elmwood Road	Hornerstown	2.86	1.79
K	Atlantic Potash Co.'s pit, Marlton	do	1.84	1.24
M-126	Coplay Cement Co.'s pit, near Osage	do	None.	.33
M-127	Eastern Potash Corporation's ground, near Eatontown.	do	None.	.26
			1.08	.56

[a] Composite sample of one-third each of M-15, M-16, and M-17.
[b] Composite sample of one-half each of M-78 and M-79.

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[71] Cook, G. H., op. cit., pp. 453-454.

[72] Idem, pp. 417-441.

The phosphoric acid and lime content of the three principal marl beds in New Jersey is relatively low, but the Manasquan marl has a greater proportion of these substances than the other two beds. On the other hand, as previously noted, it is poorer in potash.

ACCOMPANYING WATER.

At many localities the marl beds contain water, especially in the southwestern part of the State, where the elevations are generally lower than in the northeastern part. Much of the water has an unpleasant taste of iron or is slightly sulphureted and is unsuited for drinking. One sample of about 2 quarts was collected for analysis at Woodstown. A number of samples of marl collected wet were thought to contain sufficient water, singly or as composites, for analysis. The waters, however, proved insufficient for this purpose. Probably a gallon of each sample would be required for complete analyses.

By combining the supernatant water from 11 samples (M-98 to M-108 inclusive) from hole 15 and similarly the water from 10 samples (M-109 to M-118 inclusive) from hole 16, both at Elmwood Road, sufficient liquid was obtained for partial analyses, which represent the waters from these holes. The analyses of these composite samples and of sample 24 from hole 7, at Woodstown, are given in the following table. Only four of the more important substances were determined in each sample.

Partial analyses of water samples from New Jersey greensand.

[R. K. Bailey, analyst.]

	Hole 15, Elmwood Road.	Hole 16, Elmwood Road.	Hole 7, Woodstown.
	Per cent.	*Per cent.*	*Per cent.*
Soluble salts	0.029	0.0265	0.0088
SiO_2	19.10	11.37	8.32
Ca	21.40	21.07	38.10
Na	8.23	9.35	13.20
K	3.33	3.80	5.97
Undetermined	47.94	54.41	34.41
	100.00	100.00	100.00

The percentages of soluble salts in these waters are so small that the apparently substantial amounts of potassium correspond respectively to 9.6, 10, and 5.2 parts per million. This is probably far below the saturation point for potassium, for in the table showing percentages of water-soluble potash (p. 129) the content of potash, so far as given, ranges from 0.02 to 0.06 per cent K_2O, equivalent to about 0.018 to 0.05 per cent potassium. These percentages correspond respectively to 180 and 500 parts per million.

In laboratory determinations of water-soluble potash it is customary to boil the material in water for perhaps half an hour to produce the solution, whereas in the ground solution takes place at a much lower temperature and hence much more slowly. On the other hand, the water which percolates slowly through the beds has the advantage of long-continued contact with the greensand.

The disparity between the amount of potassium present and the amount required for saturation suggests that potassium is being withdrawn from solution. The silica, lime, and soda and the relatively large percentage of undetermined substances suggest that the other constituents of glauconite may be present in sufficient quantity to unite with potassium to form glauconite and that this action may be the cause of the withdrawal of potassium from solution.

That other substances are formed as well is shown by the occurrence here and there of vivianite, marcasite, iron carbonate, and phosphatic nodules.

Solution and deposition are processes that have doubtless been going on within the marl beds at different places at the same time or at the same place at different times. The present composition of the waters represents the balance between the two sets of conditions at the time of sampling.

ENRICHMENT.

POTASH.

Cook[73] states that "the best marls will always be found below the natural drainage of the country, or at least where they have never drained out to dryness." This statement does not seem to be borne out by the present investigation. In the table summarizing the field data obtained in the borings (p. 104) the thickness and potash content of each of the principal marl beds are given for each locality. The green and chocolate marl beds were in large part or entirely below the water table in four of the five localities. At the Somerdale borings, however, all the marl beds were above the water table and were practically dry, yet the potash content of each of the two beds represented (the uppermost bed had been eroded) was comparable to that of the corresponding beds at the other localities. For example, the green marl at Somerdale contained slightly less potash than that at Sewell and Woodstown but more than that at Salem and Elmwood Road.

The borings show that the green marl averages 1.1 to 1.28 per cent more in potash content than the other two beds. This difference appears to be due, in part at least, to its relatively less admixture of quartz. This is shown on the table on page 119, where the results

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[73] Cook, G. H., op. cit., p. 464.

of the magnetic separation of residues are given. Thus it is probably in the main a feature of original bedding rather than of subsequent enrichment. The green marl is usually distinct lithologically from the overlying or underlying bed. This again is probably a feature of original bedding.

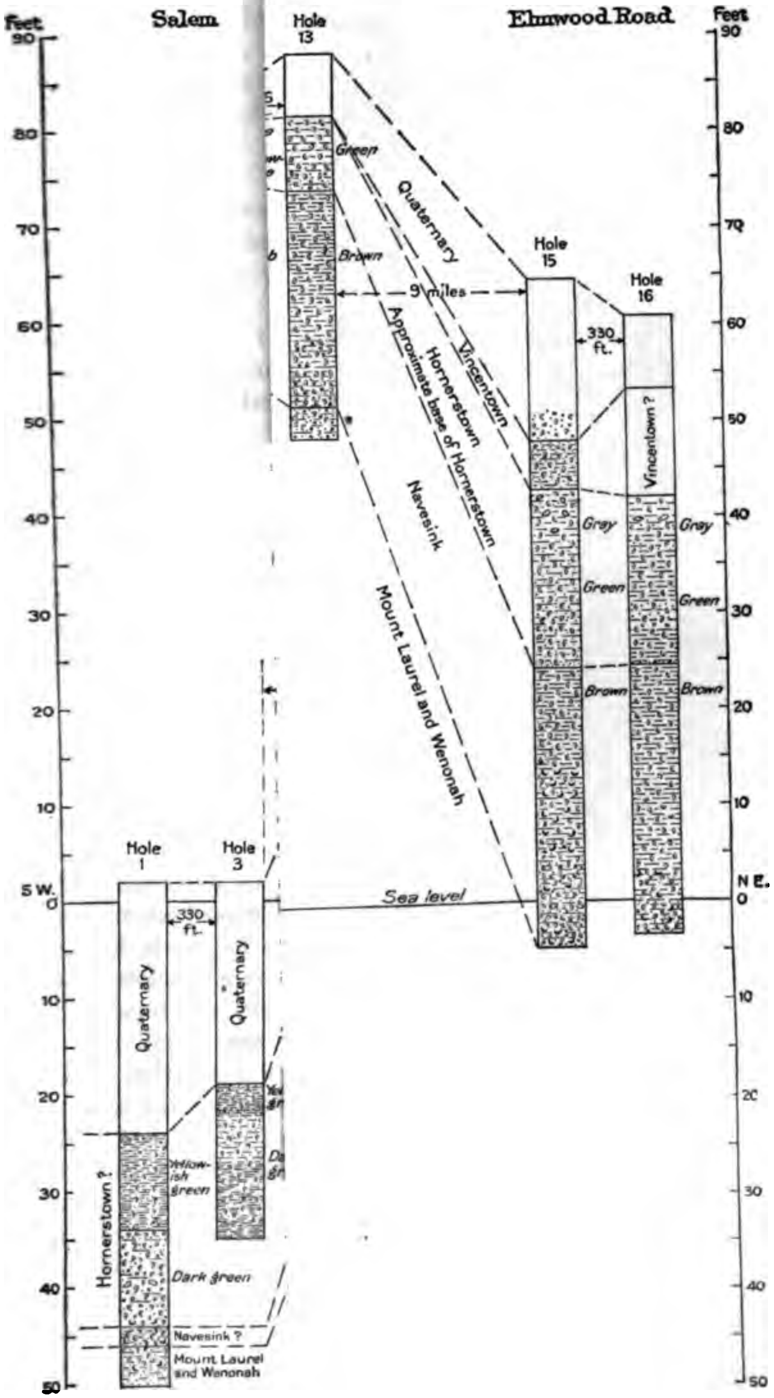
At some localities, however, notably at Sewell (see pp. 47–52), there is clear evidence of leaching and oxidation of the upper part of the marl and consequent impoverishment in potash. Although the marl beneath has a distinctly higher potash content it is not clear that this is due to enrichment rather than to original deposition. At the Somerdale borings (pp. 7, 61–64) the Hornerstown marl has been in part eroded and is overlain by reworked marl of Quaternary age. This reworked material is distinctly oxidized and contains less potash than the uneroded marl beneath, but this uneroded marl, which is part of the green bed, is not unduly high in potash.

Without doubt potash is locally being leached from the marl and is passing into solution. With little doubt, too, as suggested above, it is being abstracted from solution, but there seems to be no readily distinguishable zone of enrichment unless the green marl bed may be so considered. With regard to what becomes of this potash the following tentative suggestions are worthy of attention:

1. Clay, which is believed to have an important share in the formation of glauconite (see section on nature and origin of glauconite, pp. 138–142), was probably abundant in the original muds from which the glauconite was formed—witness the alumina present in all the analyses of glauconite and greensand cited above. It was probably more abundant in some beds than others. Thus the green marl bed with less quartz probably had a larger proportion of clay.

2. When the marl beds became part of the land area and were subjected to the action of meteoric waters the processes of oxidation and leaching of certain layers began. Some potash with other constituents went into solution and circulated through the marl beds. The potash-bearing solutions reacted with the clay to form new glauconite, and the action was more pronounced in the more clayey layers—for example, the green marl bed. Some of the new glauconite formed additions to existing grains, but some of it formed amorphous or colloidal glauconite such as that which now constitutes so marked a feature of certain beds.

3. The difference in potash content between the recent glauconites and older glauconites shown in the tables on pages 127–128 has significance in this connection, as does the remark of Collet cited with those tables. It seems quite possible that the development of glauconite begun in muds offshore may have continued by the process outlined above and may thus have enriched the undisturbed marl beds, through which the waters circulated.


Feet
Salem
Hole 13
Elmwood Road
Feet
90
80
70
60
50
40
30
20
10
5 W.
0
10
20
30
40
50
Green
Brown
Quaternary
Hole 15
Hole 16
9 miles
330 ft.
Vincentown
Hornerstown
Approximate base of Hornerstown
Vincentown ?
Navesink
Gray
Gray
Green
Green
Brown
Brown
Mount Laurel and Wenonah
Hole 1
Hole 3
330 ft.
Sea level
N E.
Quaternary
Quaternary
Yellowish green
Dark green
Hornerstown ?
Navesink ?
Mount Laurel and Wenonah

OD ROAD, N. J.

4. The changes of level to which the marl beds, together with the entire Coastal Plain, have been subjected have permitted all the marl beds, even those that now lie above the water table, to be subjected to the action of ground water for protracted periods.

OTHER SUBSTANCES.

Iron carbonate, somewhat phosphatic, forms the hard, stony layer at the base of the Hornerstown marl at hole 7, at Woodstown, and probably also forms part of certain nodules and casts that are strongly phosphatic. The stony layer is localized at a horizon that is thought to mark the boundary between two formations. The nodules and casts are distributed rather irregularly. All bear witness to the activities of solution and deposition in the circulating waters.

Ironstone, or sedimentary material cemented by oxide of iron, occurs at many places and at a number of horizons—for example, at the pit of the R. S. Ryan Co. near Medford. Here it occurs along the contact between the Hornerstown marl and the overlying Quaternary gravels. (See p. 80.) This material also bears witness to the activities of ground water. It is locally of sufficient abundance to be quarried as stone.

STRATIGRAPHIC NOTES.

Southwest of Sykesville, in Burlington County, two broad lithologic units are present—an upper formation, predominately green to greenish black, and a lower formation, brown to brownish black, the so-called chocolate marl. The contact between the two formations is well defined and usually marked by the presence of sand or gravel grains near the base of the green formation. Locally a water-bearing gravel bed, shells, or an indurated layer occur at the contact. This contact would be a convenient lithologic boundary for the Navesink and Hornerstown marls and is tentatively so considered in this paper. A single cast thought by T. W. Stanton to be that of *Cucullaea vulgaris*, a wide-ranging form but common in the Hornerstown, was taken from a gravel bed at this contact at Elmwood Road. (See Pl. X, hole 16.) It suggests that the Hornerstown includes all of the green formation at that locality.

This gravel bed and the sand and gravel grains elsewhere at the contact may represent the southwestern continuation of the Redbank sand. The stratigraphic features of the combined Hornerstown and Navesink marls at the different borings are shown in Plate X.

The Navesink grades downward into the Mount Laurel but appears to rest on a fairly uniform surface at each of the localities drilled, except at Woodstown and Sewell, where variations of about 4 and 5 feet, respectively, in distances of 330 and 375 feet down the

dip were observed. These figures would indicate a dip of 64 and 80 feet to the mile, respectively, at these localities, whereas the average calculated by Knapp, as previously stated, is only 33 feet. This apparently greater local dip may prove to be more widespread, or it may indicate local current scour in the Mount Laurel sands prior to the deposition of the Navesink.

The thickness of the Navesink is about 28 feet at Elmwood Road, 23 feet at Somerdale, 17½ feet at Sewell, 14 feet at Woodstown, and 2 feet (?) at Salem. At Salem there is no very clear basis for distinction between the Navesink and Hornerstown. The shell bed with rice gravel at the base appears to be Navesink, but the marl above in quality and appearance suggests Hornerstown rather than Navesink. At Sewell a depression in the top of the formation corresponding to that in which the base lies was observed. At Woodstown a depression of 5 feet was found in a distance of 375 feet along the strike, together with a total observed variation of 9 feet in thickness at the three holes. These features, together with the scant representation of the formation at Salem, may indicate local erosion of the upper beds by current scour or otherwise. On the other hand, at several of the holes the upper beds of the formation show a transition interval of 6 inches to several feet in which streaks of green material are intermingled with the brown.

In general the Navesink marl is more clayey at the top, less clayey and correspondingly more glauconitic in the middle, and more sandy near the base. The less clayey portions slump easily and tend to run like quicksand. At Woodstown a water-bearing gravelly layer was encountered at hole 7, which was not represented at holes 5 and 6. At Sewell a hard sandy layer with vivianite was found in hole 10 which did not occur at corresponding depth in holes 8 and 9, though in these an increasing proportion of quartz sand was noticed. At Somerdale the intermingling of brown and green material was present throughout the formation.

The basal features of the Hornerstown marl have been mentioned in connection with the description of the Navesink. The top of the formation, as represented by the *Terebratula*-bearing bed, was found in only one of the holes. Elsewhere portions of the Hornerstown had been eroded. Nevertheless the measurements show that this formation maintains or even increases its thickness toward the southwest. For example, at Elmwood Road, where the *Terebratula*-bearing bed is present, the thickness is 17 feet 7 inches. At Somerdale the formation is considerably eroded, but from 6 to 11 feet remains. At Sewell the maximum thickness measured is nearly 22 feet, at Woodstown 27 feet, and at Salem 21 feet.

In general, the Hornerstown marl as observed in these borings is more clayey and lighter in color in the upper part and more glauco-

nitic and darker below. Near the base sand and gravel grains and locally even tiny pebbles appear. Local variations may be noted. For example, at Woodstown a stony layer about 6 inches thick, somewhat phosphatic and containing much iron carbonate, occurs at the base in hole 7 but is not found in holes 5 and 6. Similarly, at Woodstown shells were present at the base in holes 5 and 7 but absent in hole 6. At Sewell a light-green clayey bed 4 feet thick at hole 8 is only 6 inches thick 375 feet away at hole 10. Other variations in color and texture were noted at different localities and at different holes in the same locality.

The three holes bored in the Manasquan marl near Pemberton were not deep enough to pass through the formation, but they showed some variations in character and thickness of the marl. The uppermost member, a relatively light colored sandy clay with comparatively little glauconite, was 3 feet thick at the first hole and more than 14 feet thick at the second, only 330 feet distant. The lower, dark-green glauconitic member was more than 9 feet thick at the first hole and less than 3 feet thick at the second. At the third hole, which was nearly a mile and a half away, only the dark-greenish member was exposed, more than 15 feet thick.

These irregularities in the greensand beds suggest that their accumulation did not take place entirely beyond the range of wave and current action.

CONDITIONS OF SEDIMENTATION.

The bedding of the greensand, as previously noted, is generally regular, so far as observed. Some beds show a fine lamination. There is more or less alternation of clayey layers with more glauconitic beds. Quartz grains, generally angular or subangular rather than rounded, are distributed somewhat unevenly throughout the glauconite beds. The sizes of the quartz grains agree in a general way with those of the glauconite, but the preponderance of the 40 and 60-mesh grains is less marked. The specific gravity of glauconite is slightly less than that of quartz, so that under the same conditions of sedimentation the glauconite grains might be expected to have a somewhat greater average size.

The distribution of the quartz grains indicates a generally steady but slow influx of land-derived material from which the more soluble rock fragments had largely been removed. The presence of the clay and glauconitic mud included with the greensand indicates generally quiet waters. The maintenance of these conditions long enough to build up such an extensive and relatively thick deposit suggests a slow subsidence of the bottom on which the deposits were accumulating or a gradual transgression of the sea upon the land. The

Vincentown and Redbank sands indicate that the glauconite-forming agencies were at times interrupted or impeded by reversal of conditions, the sea retreating or becoming shallower during the epoch of their formation. Minor reversals or oscillations of conditions during the deposition of the greensand are indicated by the presence of the sandy or gravelly layers described above.

The local variations in the thickness of the supposed Navesink marl previously mentioned suggest that from time to time the generally quiet bottom conditions were disturbed by oceanic currents or by waves.

A rather abundant and varied life inhabited the waters in which the greensand beds were being deposited, as shown by the shells and other types of fossils that have been recovered from the marl beds. Lists of these fossils are given by Clark[74] and Weller.[75] These animals furnished by their decay the organic matter generally supposed to be necessary for the formation of glauconite.

According to Murray and Renard,[76] glauconite forms most abundantly at about the lower limits of wave, tide and current action, in the neighborhood of what may be called the mud line—that is, at about 200 to 300 fathoms. The temperature of the ocean at these depths off Sandy Hook is between 40° and 45° F. If, as seems probable, the conditions of the formation of glauconite in Cretaceous time were similar to those of to-day the depth of the sea water over New Jersey in the Navesink and Hornerstown epochs was 1,200 to 1,800 feet.

NATURE AND ORIGIN OF GLAUCONITE.

Glauconite is a constituent of various marine sediments now forming along the shores of the continents, usually at depths greater than 600 feet, but ranging from about 300 feet to somewhat more than 2 miles. It is not formed in the deeper parts of the ocean, except from accidental causes, nor along coasts where great rivers, such as the Amazon, bring large quantities of sediment into the sea. It is associated chiefly with greensands and green muds, though present in blue muds, volcanic muds, and some of the oozes; and it is widely distributed in the Atlantic, Pacific, and Indian oceans and the Mediterranean Sea. Glauconite is also widely distributed in time, having been formed in all the great geologic periods.

The chemical and mineral composition of glauconite is variable, though part of the apparent variation may be due to the difficulty of procuring pure material for examination and analysis. There is

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[74] Clark, W. B., A preliminary report on the Cretaceous and Tertiary formations of New Jersey: New Jersey Geol. Survey Ann. Rept. for 1892, pp. 169-239, 1893.

[75] Weller, Stuart, Upper Cretaceous formations and faunas of New Jersey: New Jersey Geol. Survey: Ann. Rept. for 1904, pp. 145-160, 1905.

[76] Murray, John, and Renard, A. F., *Challenger* Rept., Deep-sea deposits, p. 383, diagram 2, 1891.

some doubt whether the mineral is really a definite substance. It is also thought that glauconite may include members of a series of minerals, in the same manner as the chlorites and micas.[77] Glauconite is essentially a hydrous silicate of iron and potassium and, according to Clarke,[78] probably has when pure the composition represented by the formula $Fe'''KSi_2O_6$.aq., in which some iron is replaced by aluminum, and other bases partly replace K. Thus it should contain about 13 per cent of potash.[79] The analyses show, however, that the potash is practically always partly replaced so that it rarely exceeds 7.50 to 8 per cent. Dana[80] gives the hardness of glauconite as 2 and its specific gravity as 2.29–2.35. It is usually amorphous and has a granular texture.

Glauconite occurs chiefly in tiny irregular botryoidal or rounded grains, some of which appear to be casts of foraminiferal or other calcareous shells. The greater number, however, show no direct relation to foraminiferal form. Many of the grains are worn and have evidently been transported and redeposited. Cayeux[81] describes and figures a type of grain relatively rare, in which a thin superficial coating with radial structure, visible only in thin sections with strong magnification, was observed. Collet[82] suggests that these coatings may represent glauconitic pseudomorphs after the calcite of foraminiferal shells. Another type of grain described by Lacroix[83] and relatively rare is thought to be crystalline and monoclinic. It is strongly pleochroic, has a well-recognized cleavage, and under crossed nicols in polarized light extinguishes parallel to the cleavage. Still another type, called by Cayeux pigmentary glauconite, stains the cement of consolidated sediments and forms coatings on grains of other minerals or fillings in the cracks of minerals such as feldspar.

A number of microscope slides were made showing thin sections of glauconite and of some of the associated mineral grains of different sizes from the New Jersey borings of the present investigation. The noteworthy features of the glauconite, as shown in these sections, are (1) the absence of concentric or radio-fibrous structure; (2) the absence of any skeleton or core of other mineral matter; and (3) a uniform or nearly uniform aggregate structure of tiny crystalline

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[77] Goldman, M. I., General character, mode of occurrence, and origin of glauconite: Washington Acad. Sci. Jour., vol. 9, pp. 501-502, 1919 (abstract); The petrography and genesis of the sediments of the Upper Cretaceous of Maryland: Maryland Geol. Survey, Upper Cretaceous, p. 179, 1916.

[78] Clarke, F. W., The data of geochemistry, 4th ed.: U. S. Geol. Survey Bull. 695, p. 513, 1920.

[79] Ashley, G. H., Notes on the greensand deposits of the eastern United States: U. S. Geol. Survey Bull. 660, p. 34, 1918.

[80] Dana, J. D., System of mineralogy: Descriptive mineralogy by E. S. Dana, 6th ed., p. 683, New York, 1914.

[81] Cayeux, Lucien, Contribution à l'étude micrographique des terrains sédimentaires: Soc. géol. Nord Mém., vol. 4, No. 2, p. 164, 1897.

[82] Collet, L. W., Les dépôts marins: Encyclopédie scientifique, p. 141, Paris, 1908.

[83] Cited by Cayeux, Lucien, op. cit., p. 165.

flakes, which, in polarized light, show an aggregate polarization without general extinction. (See Pl. IV, p. 6.)

The absence of skeleton or core is in distinct contradiction to the idea of Hart[84] that glauconite "consists of a core, which is apparently pure silica, and a covering layer of glauconite containing apparently no, or very little, silica."

Some grains, presumably those described on page 122 as having a platy structure or cleavage, show these features with parallel extinction in thin sections and are pleochroic. These may prove to be crystalline glauconite like that described by Lacroix. A grain of feldspar, in which flakes of glauconite had evidently been formed in cracks, was observed in one of the sections. The glauconite was apparently fresh and relatively pure and free from alteration. A few grains, however, showed encroachment of iron sulphide. The seed-like or capsule-shaped grains are isotropic. They are phosphatic and contain numerous tiny black particles that may be magnetite. Some of them contain grains of green glauconite.

The origin of glauconite is still imperfectly understood. According to Murray and Renard,[85] organic matter inclosed in the shells and present in the mud itself transforms the iron in the mud into sulphide, which may be oxidized into hydrate, sulphur being at the same time liberated. The sulphur becomes oxidized into sulphuric acid, which decomposes the fine clay, setting free colloid silica, alumina being removed in solution. The colloid silica and hydroxide of iron are in a condition most favorable for their combination, and in the presence of potash salts in sea water these substances form glauconite. Collet[86] suggests in modification of these views three stages for which he cites evidence—(1) the formation of gray casts composed exclusively of clay; (2) the formation of brown casts of different shades representing different stages in the replacement of clay by peroxide of iron, no potash being present; (3) "glauconitization," the introduction of potash and probably also of the water of constitution.

Murray and Renard[87] regard it as improbable that any minute grains of glauconite are formed in a free state in the mud. They think that this mineral is formed in the cavities of calcareous organisms, though they admit that some grains appear to be highly altered fragments of ancient rocks or coatings of glauconite on these rock fragments. They state that shells are broken by the swelling out or growth of the glauconite and that subsequently the isolated cast becomes the center upon which new additions of the same substance take place, the grain enlarging and becoming more rounded in a

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[84] Hart, Edward, Glauconite or greensand: Am. Chem. Soc. Jour., vol. 39, p. 1919, September, 1917.

[85] Murray, John, and Renard, A. F., *Challenger* Rept., Deep-sea deposits, p. 389, 1891.

[86] Collet, L. W., op. cit., pp. 176–178.

[87] Murray, John and Renard, A. F., op. cit., pp. 387–388.

more or less irregular manner, as in the formation of concretionary substances. Although the irregularities of shape and the general scarcity of grains with definite foraminiferal form may perhaps be explained in this way, the coatings and accretionary layers noted suggest that other modes of origin besides that within calcareous shells may be important.

Cayeux[88] cites a variety of evidence to show that organic matter is not essential to the origin of glauconite grains. He ascribes an important share in their genèsis to the so-called pigmentary glauconite, and shows that grains of glauconite have originated or have continued to increase in size after all the elements of the accompanying sediments were in place as in a consolidated deposit. He concludes that organic matter may be more often the primordial condition of the production of glauconite, but that it is very certain in many places that organic matter has had no part in the genesis of this mineral.

Collet[89] also recognizes the important part that pigmentary glauconite may play in the origin of glauconite grains and adds that the absence of cement in microscopic sections of glauconite may be explained by the fact that both the glauconite grains and the glauconitic cement are cryptocrystalline and composed of particles differently oriented so that suture lines would be masked.

On page 126 the fine material washed from composite samples of New Jersey greensand beds is shown to contain approximately 3 to 7 per cent of potash. It consists largely of greenish to yellowish colloidal matter that may be classed as pigmentary glauconite. It may be part of the original deposit, in which for some reason grains of glauconite did not develop, or it may have originated by mechanical wear or disintegration of previously existing grains. It may, however, have been formed by the chemical action of the circulating waters upon clay in the marl. Possibly grains of glauconite may be forming in it to-day, but of this no direct evidence was observed.

With reference to celadonite, a mineral closely related in composition to glauconite, Clarke[90] remarks:

> If, now, we assume that celadonite and glauconite are at bottom the same ferripotassic silicate, differing only in their impurities, we may begin to see that the several modes of its formation are not absolutely different after all. Probably, in all their occurrences, the final reaction is the same, namely, the absorption of potassium and soluble silica by colloidal ferric hydroxide. In the ocean these materials are prepared by the action of decaying animal matter upon ferruginous clays and fragments of potassium-bearing silicates. In the sedimentary rocks, where glauconite appears as a late

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[88] Cayeux, Lucien, op. cit., pp. 176–184.

[89] Collet, L. W., op. cit., pp. 154, 155.

[90] Clarke, F. W., The data of geochemistry: 4th ed.: U. S. Geol. Survey Bull. 695, pp. 514–515, 1920.

product, the action of percolating waters upon the hydroxide would account for its formation. In igneous rocks the hydroxide is derived from augite, or perhaps from olivine, and percolating waters again come into play. Thus the various productions of glauconite and celadonite become the results of a single process, which is exactly equivalent to that in which potassium compounds are taken up by clays. The observation of L. Cayeux that glauconite is frequently present in arable soils, in all conditions from perfect freshness to complete alteration into limonite, suggests that perhaps the formation of the species is one of the modes by which potassium is withdrawn from its solution in the ground waters.

This statement tends to confirm the suggestions presented above in the discussion of enrichment.

Fuller discussions of the nature and origin of glauconite are given in some of the papers cited, notably those of Cayeux and Collet, which contain bibliographies of the subject.

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BULLETIN [redacted]

DEPARTMENT OF THE INTERIOR
ALBERT B. FALL, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Bulletin 728

THE OCCURRENCE AND USES OF PEAT IN THE UNITED STATES

BY

E. K. SOPER AND C. C. OSBON

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THE OCCURRENCE AND USES OF PEAT IN THE UNITED STATES.

By E. K. Soper and C. C. Osbon.

INTRODUCTION.

SCOPE AND PURPOSE OF THE REPORT.

This report, which contains the results of studies undertaken during the World War, describes the peat deposits of the region lying east of the ninety-seventh meridian and north of an irregular line drawn eastward through the northern parts of Iowa, Illinois, Indiana, Ohio, Pennsylvania, and New Jersey, including approximately the area covered by the Wisconsin or last glacial drift; a relatively narrow strip of land extending 25 to 50 miles inland on the Atlantic coast from New Jersey to southern Florida and along the Gulf coast to the Mexican boundary; and small scattered areas in the Pacific Coast States. (See Pl. I.) These regions include practically all the valuable peat deposits in this country and nearly all the swamp land except the bayous and lowlands along the Mississippi, where peat can not form because the water contains too much sediment and the heavy rainfall is unevenly distributed throughout the year.

It has been known for many years that the United States contains large deposits of peat, but little detailed information concerning the quantity and quality of this peat or the uses for which it is best adapted has heretofore been available except some reports on the peat deposits of Maine and a few other States. This report is intended to show the method of formation, distribution, quantity, and quality of the peat in the United States, to indicate the uses for which it is best suited, to point out the possibilities offered by the commercial utilization of peat, and to serve as a guide for future investigations. It contains conclusions based on a study of the origin, occurrence, and distribution of peat in the areas considered, a general account of the uses of peat and peat moss for fertilizer, fuel, surgical dressings, and other purposes, and descriptions of the methods of measuring and testing peat deposits and of the processes of manufac-

turing peat products; but as complete descriptions of machinery and manufacturing methods are given in other publications, references to which will be found in this report, the technical features of the work of peat production are treated only briefly.

PERSONNEL AND ACKNOWLEDGMENTS.

The geologic field work in Minnesota, Wisconsin, New York, the New England States, Pennsylvania, and New Jersey on which this bulletin is based was done during the summers of 1914, 1915, and 1918, mainly by E. K. Soper, who was assisted in Minnesota by Percy G. Cowin. Data concerning the occurrence of peat in Virginia and North Carolina and the commercial and economic conditions of the peat industry were gathered by C. C. Osbon in 1917, 1918, and 1919. The report was jointly written by Messrs. Soper and Osbon. Some of the information presented is based on the work of the late Charles A. Davis and of the geological surveys and other organizations of the States that contain peat deposits.

The work was done under the general supervision of David White, chief geologist of the United States Geological Survey, to whom the authors are especially indebted for many helpful suggestions. Acknowledgments are due to R. G. Butler for collecting samples of peat and related data in Illinois, Indiana, Ohio, and Michigan in the summer of 1918, to Prof. W. H. Emmons for the loan of field equipment and for other assistance, to Dr. George E. Nichols for valuable data concerning the occurrence of peat and peat moss in Massachusetts, to Dr. George H. Perkins for data concerning the bogs of Vermont, to E. A. Beals for information relating to certain peat deposits in Connecticut, to R. R. Hice and O. E. Jennings for data regarding peat and sphagnum in Pennsylvania, to Alfred Dachnowski for data respecting certain peat areas in Massachusetts, and to Frederick V. Coville and W. C. Alden for reading the entire report and offering valuable suggestions for its improvement. The aid given in the preparation of this report by the operators and engineers of peat plants throughout the country, by numerous State officials not mentioned above, and by others whose personal assistance and courtesy materially contributed to its value is most heartily acknowledged.

PROSPECTS OF THE PEAT INDUSTRY.

Peat is used in the United States principally in agriculture. Its value as a source of nitrogen for use in the fertilization of the soil seems to have been overlooked by many who are interested in the development of a domestic peat industry. Analyses of the peats of the United States show a content of nitrogen ranging from 1 to 4 per cent and averaging about 2 per cent, much of which can be ex-

tracted from the peat as a by-product in producer-gas plants or by simple treatment can be made available for plant food without segregating it from the peat. However, a chemical analysis of raw peat is not a true test of its value as a source of nitrogen for agricultural use, for by proper inoculation with nitrifying organisms a substantial quantity of soluble nitrogen is gradually formed and released after the peat has been placed on the soil. Moreover, prepared peat, when added to some soils, either directly or as an ingredient of commercial fertilizer, improves their physical make-up.

Peat has been used commercially in the United States as a fertilizer since 1908. It has been mixed with potash or phosphate, limed, treated with nitrifying bacteria, and applied directly to the soil as a fertilizer, or it has been dried, screened, and used as a nitrogenous ingredient of commercial fertilizers. This subject is now attracting wide attention, and the use of peat in agriculture probably offers greater possibilities in this country than in any other. Raw and strongly acid peat is also used without nitrification in the cultivation of rhododendrons, orchids, blueberries, and other plants that require acid soil and are able to use nitrogen in organic form.

The use of peat and muck as crop soils is being rapidly extended in this country and abroad.

Peat has been used as fuel for centuries, notably in Russia, Denmark, Sweden, Ireland, Germany, and Holland. It was not used as fuel commercially in America before 1908, although immigrants familiar with its use as fuel in their native lands, who came here and settled in our northern States or migrated westward frequently used it for heating and cooking prior to that time. The early settlers in the New England States and some of the pioneers who settled on the prairies of Minnesota, Wisconsin, and northern Iowa before railroads were built and coal could be readily obtained thus made use of peat as fuel.

Although peat in the form of hand-cut blocks was produced as fuel by the early settlers in the United States, the first attempt to manufacture peat fuel commercially in this country was made in 1902, when a strike of the Pennsylvania miners caused a shortage of coal and directed attention to the peat deposits of the country as a source of fuel. Since then many experimental plants have been built, but few have reached the stage of commercial production. The most common causes of failure have been lack of sufficient capital, choice of improper methods and machinery, and injudicious location of the plants where coal was abundant or easily procured.

Although peat fuel has long been profitably produced and sold in Europe, where labor is cheap and coal is scarce, a peat-fuel industry of national proportions would probably not be successful in the

United States so long as our vast reserve of coal remains available. However, the coal shortage of 1917 and 1918 showed that peat fuel may be profitably made and sold in regions where coal is scarce and expensive, where good peat is abundant, and where, on account of a cold climate and extensive manufacturing industries, large quantities of fuel are needed. Although the prospects for a commercially successful peat-fuel industry in the United States are now probably limited to regions remote from the coal fields, it seems that ultimately, when our reserve of high-grade coal is consumed, there will be a general demand for other fuel, and unless heat and power are obtained from other sources a large peat-fuel industry will be created in this country.

The other commercial uses of peat are numerous and varied. Many valuable by-products, similar to those obtained by distilling coal, may be produced from peat. In the manufacture of stock feed screened peat is used as an absorbent for the uncrystallized residues of beet and cane sugar refineries and as a corrective of intestinal disorders. Owing to the scarcity of raw materials in Europe, fibrous peat is there employed to some extent in making paper, cardboard, artificial wood, and cloth; and sphagnum or peat moss has been extensively used since 1914 as a substitute for absorbent medicated cotton in surgical dressings. In Europe and in the United States use has been made of especially prepared peat and peat moss for mud baths, packing material, and stable litter. A detailed discussion of some of these subjects is given on pages 59–74.

DEFINITIONS.

The terms "peat" and "muck" are often used interchangeably to designate either of those materials—a practice that is confusing and that should be discouraged. Peat is the partly carbonized organic residuum produced by an arrest in the decomposition of roots, trunks of trees, twigs, seeds, shrubs, mosses, and other vegetation covered or saturated with water. It contains a large proportion of the carbon of the original vegetable matter, and its vegetal structure is generally visible without the microscope. It is usually acidic, and it contains much less inorganic than organic matter. In fact, some pure peats contain less than 4 per cent of inorganic material. Muck is soil that contains a high percentage of uncarbonized organic matter; but, as the name is commonly applied to drained and oxidized areas of peat under cultivation, it is difficult to draw the line between peat and muck; peat may grade into muck and muck into peat. If the material will ignite and burn freely when dry it is usually considered peat.

ORIGIN OF PEAT.

GEOLOGIC CONDITIONS FAVORABLE TO THE FORMATION OF PEAT.

Peat is formed under conditions favorable to the profuse growth of plants and to the escape of the plant débris from complete decomposition by bacterial and chemical action. Hence it is clear that the accumulation of this material is governed very largely by topography—that is, the configuration of the surface of the land—and by climate. If the land surface contains depressions, or flat or gently sloping, poorly drained areas in which water may collect and stand permanently, and if the temperature of the air and the soil is low in summer or the humidity of the air is high enough to prevent rapid evaporation, peat-forming plants will flourish.

Glaciation was the dominant factor in the distribution and origin of most of the peat deposits in the United States as well as of many in Canada and Europe. During the glacial epoch a succession of great ice sheets spread southward from Canada over New England, New York, the northern parts of New Jersey and Pennsylvania, and nearly all the region north of Ohio and Missouri rivers. As each sheet in turn melted away it left on the surface of the land irregular deposits of glacial drift consisting of clay or rock flour, sand, gravel, and boulders that had been carried by the moving ice and its attendant waters. In many places this drift so blocked the stream valleys as to form lakes. The unevenness in the thickness of the drift or its irregular settling produced many hollows, and the scouring action of the moving ice on solid rock produced still others.

The earlier ice sheets disappeared so long ago that streams have now drained most of the lands they covered, notably parts of Nebraska, Kansas, Iowa, Missouri, and Illinois. But though the last ice sheets, those of the Wisconsin stage, melted ages ago the streams have not yet had time to clear out and extend their valleys so as to drain the thousands of lakes and ponds and the hundreds of thousands of acres of marsh and swamp land in the region covered by the last glaciers. For this reason the peat bogs are confined largely to the area of the latest glacial drift, though basins in which peat may accumulate are also formed in limestone regions by solution.

The factors next in importance to glaciation and the kind of surface rock in forming deposits of peat are wave and stream action and coastal subsidence. Many peat deposits of salt-marsh and fresh-water origin are seen in drowned valleys, where the coast has subsided and landlocked lagoons or deltas have been formed, and in flat, imperfectly drained areas farther inland. In some places salt-marsh peat overlies peat of fresh-water origin, indicating coastal subsidence.

Abundant and well-distributed rainfall, high humidity, and a cool or moderate temperature are the most favorable climatic conditions for the formation of peat. These conditions are found in the region of the Great Lakes, in the New England States, and, in varying degrees of competency to form peat, in the Atlantic Coast States. If the climate is otherwise suitable, peat forms at some places in the Frigid Zones, but not extensively. In the Torrid Zone, although, owing to the high temperature, plant débris decays rapidly, despite the profuse plant growth peat accumulates slowly and therefore contains a high percentage of inorganic matter.

On account of the rapid run-off of surface waters in the Appalachian and Rocky Mountain regions little valuable peat is formed, and scanty rainfall produces the same result in the area between the Rocky Mountains and the eastern part of the Dakotas. Contrary to the general belief, there are few commercially valuable deposits of peat in the lower Mississippi Valley, perhaps because of the high temperature and the vast amount of alluvium carried by the Mississippi and its tributaries and deposited from time to time on its flood plain.

CHARACTER OF PEAT-FORMING VEGETATION.

As peat consists of partly decayed and disintegrated plant débris, the function performed by plants in the origin of peat is fundamental. Although hundreds of different plants have been identified in the bogs and swamps of this country and thousands of species have contributed material to form peat, comparatively few plants contribute the greater part of the vegetable débris that makes it. The most common of these plants are trees, heath shrubs, sedges and grasses, mosses, pondweeds, water lilies, reeds, cat-tails, algae, and ferns. In a favorable environment most of these plants multiply rapidly and soon predominate over their competitors; in fact, in some areas they grow so densely that man can penetrate them with difficulty, and an immense quantity of dead vegetation annually accumulates.

CHEMICAL CHANGES IN PEAT-FORMING MATTER.

One of the chief substances formed by plants during their growth is cellulose ($C_{72}H_{120}O_{60}$), which consists of carbon, hydrogen, and oxygen. These constituents are absorbed by the leaves from the atmosphere and by the roots from the soil. Cellulose, because of its complex composition, is an unstable compound and when attacked by fungi and bacteria decomposes rapidly. If at the end of the growing season the plant débris falls upon drained soil it is vigorously attacked by these microorganisms, and the carbon and hydrogen of the cellulose unite with the atmospheric oxygen and with

each other, forming carbon dioxide, water, and marsh gas. In other words, if oxidation is unhampered, the organic matter will disappear in a relatively short time. If, however, the plant matter falls into water or upon soil saturated with moisture, it undergoes a change different from the decay suffered by exposed vegetation. The atmospheric oxygen is largely excluded, and as the activity of fungi and bacteria is controlled by the supply of air, upon which they depend for their existence, decay is slow, the plant débris becomes buried, and a large proportion of the fixed carbon is retained. The salient features in the production of peat ($C_{62}H_{72}O_{24}$) from cellulose ($C_{72}H_{120}O_{60}$) are the elimination of hydrogen and oxygen as water (H_2O) and of carbon and oxygen as carbon dioxide (CO_2) and the generation of methane (CH_4). This is the process of carbonization.

If the surface conditions are unchanged, carbonization is largely arrested with the formation of peat, and the accumulation of organic matter may exist indefinitely as peat, unless the land is drained and decomposition begins again or unless the peat is deeply buried beneath superposed deposits, generally muds, sands, limestone, and other sedimentary beds, and subjected to pressure, accompanied by heat. Lignite, bituminous coal, anthracite, and graphite are succeeding stages in the process of carbonization of the buried vegetable débris. Most coals were once peats; most coal fields were formerly swamps, and the formation of peat in the bogs and swamps of this country to-day is an example of the first stage in the process of coal formation. Deposits essentially similar were laid down in many parts of the United States during the Carboniferous, Triassic, Cretaceous, and Tertiary periods.

CLASSIFICATION OF WET LANDS AND PEAT DEPOSITS.

TYPES OF UNDRAINED LAND.

The terms "bog," "marsh," and "swamp" are often used interchangeably to indicate the same kind of undrained land surface. It is suggested that, for the sake of exactness, these terms should be used to designate the following types of undrained lands:

Bog.—A flat or gently sloping wet area devoid of trees, except in some places small scattered patches of tamarack or black spruce, and overgrown principally by sphagnum moss and heath shrubs or by grasses and sedges. The numerous sphagnum areas of Minnesota, Wisconsin, and the New England States belong to this class.

Marsh.—An open shallow basin or relatively flat area covered with water, devoid of trees, and overgrown by grasses, sedges, cattails, bulrushes, or reeds. The chief difference between bogs and

marshes lies in the character of the living vegetation and the quantity of surface water. Marshes often adjoin lakes, rivers, and seacoasts and may contain either fresh or salt water. The Revere Marsh, near Boston, Mass., is a typical salt marsh, and the marshes adjoining Charles and Neponset rivers in Massachusetts are good examples of the fresh-water type.

Swamp.—A low, flat area covered or saturated with water and overgrown by trees, with or without an undergrowth of shrubs. The surface may be overgrown by a thick mat of vegetation, consisting of small plants, a condition found in many of the swamps of New England, or, as in some parts of Dismal Swamp, Va., it may be covered with water and comparatively free from small plant growth. Swamps are sometimes named from the trees that predominate in them, as spruce swamp, cedar swamp, gum swamp, and cypress swamp. In swamps containing standing water the contribution of sphagnum moss and heath shrubs to the débris from which peat forms is small.

KINDS OF PEAT DEPOSITS.

TOPOGRAPHIC TYPES.

As classified according to topography, there are three general types of peat deposits—the filled basin, in which the peat accumulates in marshes, ponds, and lakes; the built-up deposit and its corollary, the climbing bog, in which the peat forms on flat or gently sloping moist areas not covered with water; and the composite area consisting of built-up peat underlain by peat of the filled-basin type. Plate II illustrates the first two types. Although deposits of all three kinds are found throughout the peat regions, the filled-basin type predominates. Built-up peat forms on areas where the drainage is so greatly interrupted that the soil becomes permanently saturated with moisture. As shown by deep test borings, large areas now covered with built-up peat are underlain by fine-grained peat composed of the remains of aquatic plants, indicating that the built-up stage was preceded by a long period of subaqueous peat formation. The most extensive deposits of lake and built-up peat are in the Great Lakes region and the New England States; and the most extensive deposits of marsh peat are in the Atlantic Coast States. Large climbing bogs are found in Maine, and some are found in other New England States.

FLORAL TYPES.

As classified according to dominant plant growth, the eight common types of peat areas are as follows: (1) Pondweed basins, (2)

A. FILLED-BASIN PEAT DEPOSIT.

The old shore line (1) is visible.

B. BUILT-UP PEAT DEPOSIT FORMED ON A RELATIVELY FLAT SURFACE.

TYPES OF MATURE PEAT DEPOSITS

grass-sedge marshes, (3) sphagnum-heath bogs, (4) cedar swamps, (5) spruce swamps, (6) tamarack swamps, (7) gum swamps, and (8) cypress swamps.

PEAT-FORMING FLORAS.

FILLED BASINS.

Beginning at the center of basins filled with water and proceeding shoreward, the usual sequence of vegetation, depending to a large extent upon the depth of the water, is algae and stoneworts, pondweeds, water lilies, bulrushes, and amphibious sedges. (See Pl. III.) Sphagnum and heath shrubs sometimes grow on the marginal zones and are abundant on the quaking bogs of the Northern States. In the northern peat region a growth of tamarack and spruce is often found near the water, and in the Atlantic coastal area a zone of gum and cypress, but these trees are not large contributors to the filled-basin peat. Adjoining zones of vegetation usually overlap, and some plant zones may be absent. As the quantity of surface and underground water and the acidity or alkalinity of the underground water largely determine the flora of a region, and as the gradual accumulation of peat lessens the depth of the water in a peat-forming basin, the vegetal sequence mentioned gives a fairly reliable index to the general dominant plant associations that successively enter into the development of a filled-basin peat deposit.

The following stages of plant growth usually predominate in the order given in peat-forming basins that contain alkaline waters: (1) Stonewort and water weed (*Chara-Philotria* association), (2) pondweed and water lily (*Potamogeton-Nymphaea* association), (3) rush and wild rice (*Scirpus-Zizania* association), (4) meadow sedge and grass (*Carex* association).

Some filled-basin peat deposits, however, because of the influence of fire, drought, and drainage, were not formed by the successive growth and decay of all these plant associations. Changes in the surface water from alkaline to acid also affect the composition of the floras. Fine-grained algal peat is usually found at the bottom of filled-basin deposits, indicating that they had at least a normal origin. This material is generally overlain by strata of weed, sedge, and grass peat. Algal peat is usually not found in shallow filled-basin deposits, showing that the second plant association took root in the shallow water soon after the basin was formed and prevented the dominance of algae and other cryptogamic plants. The mass of peat in some filled-basin deposits consists of fibrous material produced chiefly by the decomposition of sedges and grasses, indicating that the meadow stage predominated for a long time. If a filled-

basin peat deposit is destroyed by fire, the first stage in the usual succession of plant growth is often resumed after the basin is again filled with water, but if subjected to drainage or drought the earlier stage in the succession of vegetation may, if like conditions prevail, be replaced by bog-heath plants.

BUILT-UP BOGS.

As built-up peat accumulates on level or gently sloping surfaces the plant associations that successively predominate in peat-forming basins do not materially enter into its formation. As shown by Plate III, the stages of plant growth that contribute to built-up peat are as follows: (1) Bog-heath (*Andromeda-Ledum* association); (2) tamarack-spruce (*Larix-Ledum* association) in the northern region; or (3) gum-cypress (*Nyssa-Taxodium* association) in parts of the Atlantic coastal region.

When built-up deposits are consumed by fire the process of peat formation again begins with the bog-heath stage, unless the area surrounding it is overgrown with trees, and then it is sometimes resumed with the more advanced stage. The permanent flooding of a built-up bog would convert it into a marsh, and if drained to the depth of a few feet the formation of peat in built-up bogs is usually stopped.

As built-up deposits are largely formed by heath shrubs and mosses, the peat usually consists of the remains of only a few plant forms and is therefore relatively homogeneous. Often the peat consists almost entirely of partly decayed sphagnum, especially in the coniferous forest region. Some built-up deposits are overgrown by plants of the same kind that formed the mass of the peat in them, indicating uniform climatic and topographic conditions for a long time. In many deposits, however, the floral development is more advanced and heath shrubs and trees predominate. Many extensive built-up bogs in the coniferous forest areas of the Northern States are in the heath or tree stage.

COMPOSITE AREAS.

As composite peat areas consist of filled-basin peat overlain by peat of built-up origin they can not be distinguished from built-up deposits by surface criteria. Their history can be ascertained only by numerous test borings and by careful study of the topography and of the plant remains. All the normal stages of plant development may enter into the formation of composite peat, and many of the deposits therefore contain successive strata of algal, rush, grass, sedges, sphagnum, shrub, and tree peat.

A. SUCCESSIVE ZONES OF GROWTH OF (1) PONDWEED AND WATER LILY; (2) SEDGE; (3) SHRUB; AND (4) FOREST TREES.

B. SUCCESSIVE ZONES OF GROWTH OF (1) HEATH GRASSES; (2) SHRUBS; AND (3) FOREST TREES.

PEAT-FORMING BASINS.

PROCESSES OF FORMATION.

FILLED BASINS.

Fresh-water peat.—Most of the peat deposits of this country were formed by the accumulation of plant débris in ponds, fresh-water marshes, and lakes and are called filled-basin deposits. (See Pl. III.) The numerous peat-forming lakes and ponds in all developmental stages found in many parts of the Great Lakes and New England States afford ample evidence of the processes by which the other deposits formed. Test borings usually show that fine-grained peat produced by the decomposition of algae and other cryptogamic plants, the first to grow in deep water, constitutes the bottom layer of the deep deposits. Coincident with the formation of algal peat in the deep water, pondweeds, water lilies, sedges, and other plants that take root in shallow water established themselves on the margins of the basins. Thus the basins were gradually filled with plant débris from the bottom and from the shores. The formation of algal peat is relatively slow, but after the water becomes shallow enough for the growth of pondweeds and sedges in all parts of the basin the peat accumulates rapidly and soon fills the depression. When and where the surface of the deposit is raised to the general level of the surrounding country, herbs, sphagnum, and heath shrubs appear, and if moisture is abundant, the filled-basin process will be followed by the formation of built-up peat.

Salt-marsh peat.—Salt-marsh peat, though formed in practically the same manner as fresh-water peat, differs from it somewhat in character. Few seed plants tolerate salt water, and the number of plant varieties found in salt marshes is therefore rather small. The most common types are salt-marsh grasses, rushes, and sedges. The entire vegetation of some of the New England salt marshes consists of one dominant and two or three subordinate species.

In some of the coastal marshes of New England salt-marsh peat is underlain by peat of fresh-water origin, indicating the subsidence of that part of the Atlantic coast. Bastin and Davis[1] in discussing the origin of certain peat deposits on the coast of Maine said in substance:

> Some persons think that these overlying strata of salt-water peat were formed in bays or inlets which had been cut off from the ocean by barrier beaches and to which salt water was subsequently admitted by wave or current action. This explanation, however, is not satisfactory, because the salt-water peat, which was formed from the remains of plants similar to those now growing in these marshes, plants that can not exist even a few inches above their present level, is 8 feet thick or more in many places. It therefore seems improbable

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[1] Bastin, E. S., and Davis, C. A., The peat deposits of Maine: U. S. Geol. Survey Bull. 376, pp. 20–21, 1909.

that the salt marshes in which this material accumulated were made by the action of waves or currents. A more plausible explanation of the character of these deposits presupposes the gradual subsidence of a coast containing scattered fresh-water marshes in which peat was forming. As the sinking of the coast continued these marshes were filled with salt water, and peat formed from the decay of salt-water plants was deposited upon the fresh-water peat. If this theory is correct the thickness of the salt-water peat indicates that the coast has been sinking at the rate of about a foot a century. As the fresh-water deposits are both underlain and overlain by salt-water peat in some places it seems that a slight uplift of the coast preceded the present period of subsidence.

BUILT-UP BOGS.

Peat deposits formed by the accumulation of plant matter on level or gently sloping surfaces are called built-up bogs. Plate II illustrates a typical built-up bog. Mosses, grasses, herbs, and heath shrubs contribute the dead vegetation, and the water, though it may never rise above the surface, is progressively elevated as the peat collects. Surface conditions are little changed from year to year, and hence built-up bogs are relatively homogeneous in structure.

COMPOSITE AREAS.

When a basin deposit is filled with peat to the level of the surrounding country it is mature, and if the moisture is sufficient the built-up process begins. Mosses, herbs, and heath shrubs displace the pondweeds, water lilies, sedges, and like plants, and thenceforth the deposit develops the same as if it had originated on a relatively level land surface not covered with peat. The result is a composite peat deposit. The peat may accumulate to a thickness of many feet above the former water level in the basin. Composite areas are recognized by a marked change in the structure of the peat where the pondweeds, water lilies, and sedges were displaced by bog plants.

RATE OF FORMATION.

As the formation of peat depends upon many factors the rate of its accumulation varies widely from year to year. If the climate, topography, and vegetation are favorable, peat forms rapidly; but if one or more of these is relatively unfavorable, the rate of accumulation is retarded. Although most of the large deposits of peat in the United States have been examined, no definite evidence has yet been obtained to show the rate of their formation. Even under the most favorable conditions it is too slow to be measured by ordinary observation. Persons who have lived near peat-forming basins for half a century are unable to see the slightest change in the appearance or depth of the peat, although careful examination shows that it has been forming continuously. Dana[2] gives the rate as 1 foot in 5 or 10

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[2] Dana, J. D., Manual of geology, 4th ed., p. 154, 1895.

years, but this probably far exceeds the average rate of formation in the United States. The only reliable means of making even a rough estimate of the rate at which peat is formed seems to be to estimate the average thickness of some of the largest deposits in the Great Lakes States and the time that has elapsed since the Wisconsin stage of glaciation. As already stated, most of the peat deposits of the Great Lakes States originated in glacial lakes and ponds or on flat, poorly drained areas formed by topographic changes due to glaciation. By assuming that peat began to accumulate in certain typical lakes and ponds soon after the final recession of the ice sheet, that 10,000 to 30,000 years have elapsed since the close of Wisconsin glaciation, that the average thickness of these deposits is about 18 feet, and that the formation of the peat was uninterrupted, we may compute the average rate of accumulation per century at 0.72 to 2.16 inches. But as field study shows that fire, flood, and drought have interrupted the formation of peat in many of the large deposits these figures are only speculative, and as the water level in practically all peat areas varies with fluctuations in annual precipitation (and such variations materially affect the formation of peat) it is evident that the rate of formation in most peat deposits has not been uniform.

PROPERTIES OF PEAT.

PHYSICAL COMPOSITION.

GENERAL FEATURES.

Native peat consists of partly decayed vegetable matter, inorganic minerals, and water in varying proportions, the usual ratio being 10 per cent of solid matter to 90 per cent of water. In specific gravity it ranges from 0.1 to 1.06 and in weight from 7 to 65 pounds per cubic foot. Aside from its high water content, peat is extremely variable, and scarcely any two deposits contain material that is exactly similar in physical properties. This diversity is due to many causes, the most notable of which are the variety of plants from which the peat was formed, and differences in climate, in the ages of the deposits, in water level, and in the quantity of sediment deposited during the accumulation of the peat.

TEXTURE.

The texture of peat depends upon the kinds of plants from which it was formed and the physical conditions under which it accumulated. Peat formed from algae and mosses is fine grained and comparatively homogeneous, whereas peat produced by the decay of grasslike or woody plants is generally fibrous and poorly decomposed unless decay has progressed unusually far. Peat formed by the decomposition of shrubs and trees is generally woody in struc-

ture. Dead vegetation of any kind that is exposed for long periods to the free action of fungi and bacteria becomes thoroughly disintegrated and fine in texture. Peat that accumulates in river valleys and lakes whose water contains much sediment is usually too impure and contains too much ash for commercial use.

The following classification[a] of peats by physical characteristics includes all types found in the United States:

Turfy peat.—Consisting of slightly decomposed mosses and other peat-producing plants, having a yellow or yellowish-brown color, very soft, spongy, and elastic; specific gravity, 0.11 to 0.26, the full English cubic foot weighing from 7 to 16 pounds.

Fibrous peat.—Unripe peat which is brown or black in color, less elastic than turfy peat, the fibers either of moss, grass, roots, leaves, or wood, distinguishable by the eye, but brittle and easily broken; specific gravity, 0.24 to 0.67, the full cubic foot weighing, accordingly, from 15 to 42 pounds.

Earthy peat.—Nearly or altogether destitute of fibrous structure, drying to earthlike masses which break with more or less difficulty, giving lusterless surfaces of fracture; specific gravity, 0.41 to 0.90, the full cubic foot weighing from 25 to 56 pounds.

Pitchy peat.—Dense; when dry, hard; often resisting the blows of a hammer, breaking with a smooth, sometimes lustrous fracture into sharp-angled pieces; specific gravity, 0.62 to 1.08, the full cubic foot weighing from 38 to 65 pounds.

The peat deposits of Minnesota, Wisconsin, and Michigan were produced chiefly by the decomposition of mosses, sedges, grasses, heath shrubs, and trees, and their texture varies from fibrous in the upper layers to plastic in the lower. The deposits of Iowa, Illinois, Indiana, Ohio, Pennsylvania, New York, and New Jersey consist largely of the remains of grasses, mosses, rushes, cat-tails, and reeds, and are somewhat similar in texture. On the whole, however, the peats of the second group, those of the southern Lake States, are more fibrous than those of the first, and, except in northern Indiana and northeastern Pennsylvania, are relatively free from the remains of sphagnum moss. Sphagnum peat is abundant in the bogs of northern Minnesota, Wisconsin, and Michigan and in Maine, and some is found in the other New England States and New York. Pondweeds, pond lilies, heath shrubs, rushes, cat-tails, and coniferous trees were also large contributors to the peats of Maine and of the other New England States. Grasses are the dominant form of plant life in the salt marshes on the New England coast, notably the genus *Spartina*, and grass peat is therefore abundant in this area. The peats of the Atlantic Coastal States south of New Jersey are very different in composition and texture from those of the Great Lakes region and the New England States. There is relatively little sphagnum in the Atlantic coastal region, and both coniferous and deciduous trees con-

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[a] Johnson, S. W., Peat and its uses, pp. 95–96, New York, 1866.

tributed a large proportion of the vegetable débris from which the peat was formed.

COLOR.

Peat ranges in color from light yellow through various shades of brown to jet black, the color representing in a measure the degree of decomposition. Peat that is new or that has been well protected from the air is usually light yellow or brown; well-decomposed humified peat is jet black. Green peat, produced by the decomposition of algae and related aquatic plants, is found at the bottom of some filled-basin deposits. On drying in the air most peats become brighter in color, except the very light varieties, which usually change to dark brown or black after being macerated and dried. Peat that is red, gray, or white in spots or feels very gritty when crushed between the teeth contains too much inorganic matter for commercial use as a fuel.

WATER-HOLDING CAPACITY.

The affinity of peat for moisture is proverbial. In fact, as previously explained, peat can not form unless the plant débris is saturated or covered with water. The peat in most deposits contains about 90 per cent of moisture, which is held both mechanically and chemically in the plant cells and intercellular spaces. In other words, a short ton of typical raw peat consists of about 200 pounds of solid matter to 1,800 pounds of water. The reduction of this high content of moisture is the paramount necessity in the commercial utilization of peat. Many attempts have been made to remove the excess moisture by compression, but it resists the strongest pressure obtainable and can be materially reduced economically only by evaporation.

Relation between solid and liquid constituents of a ton of typical raw peat as its water content is progressively reduced from 90 to 10 per cent.[a]

Per cent of water in peat.	Quantity of water eliminated for each reduction of 10 per cent (pounds).	Cumulative quantities of water eliminated (pounds).	Weight of peat after each 10 per cent reduction of water content (pounds).	Quantity of water (pounds).	Quantity of solid matter (pounds).
90	....	....	2,000.0	1,800.0	200
80	1,000.0	1,000.0	1,000.0	800.0	200
70	333.3	1,333.3	666.7	466.7	200
60	166.7	1,500.0	500.0	300.0	200
50	100.0	1,600.0	400.0	200.0	200
40	66.7	1,666.7	333.3	133.3	200
30	47.6	1,714.3	285.7	85.7	200
20	35.7	1,750.0	250.0	50.0	200
10	27.8	1,777.8	222.2	22.2	200

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[a] Davis, C. A., Uses of peat for fuel and other purposes: Bur. Mines Bull. 16, p. 110, 1911.

The accompanying diagram (fig. 1), which is based on the foregoing table, shows graphically the relation between the weight and water content of raw peat.

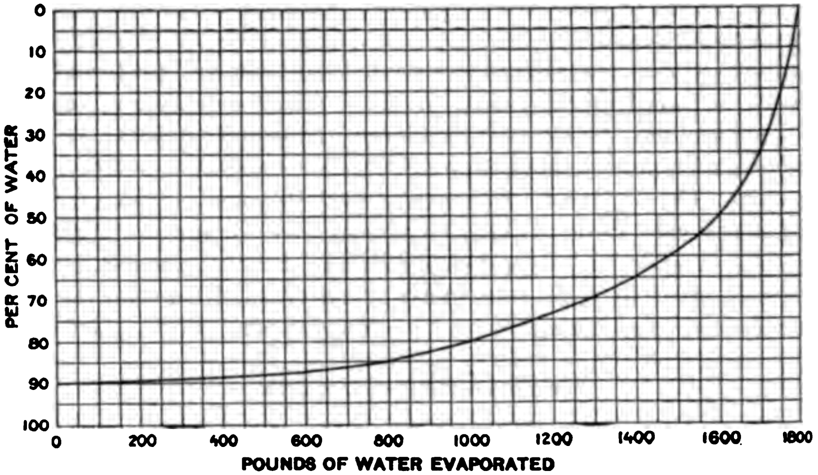

FIGURE 1.—Diagram showing relation between the weight and water content of a ton of raw peat at different stages of evaporation.

CHEMICAL COMPOSITION.

GENERAL FEATURES.

A detailed study of the chemical properties of more than 500 samples of peat taken from deposits in different parts of the peat regions of this country leads to the following conclusions:

Peat consists of carbon, hydrogen, oxygen, and relatively small quantities of nitrogen. Although the exact atomic relations of its principal elements are not known and probably are not constant, the formula $C_{62}H_{72}O_{24}$ is typical. The composition of peat is illustrated by the following analysis (ash and moisture omitted):

Composition of peat.

Carbon	59.50
Hydrogen	5.50
Oxygen	33.00
Nitrogen	2.00
	100.00

The quantity of "fixed" or "free" carbon generally ranges from 10 to 60 per cent, the remainder being combined with other elements. Volatile matter usually ranges from 25 to 70 per cent and moisture from 15 to 30 per cent in air-dried peat. As the volume of oxygen is relatively high, good peat ignites readily and burns freely, leaving

little unconsumed residue. Sulphur usually ranges from 0.2 to 0.6 per cent and nitrogen from 1 to 4 per cent, the average for nitrogen being about 2 per cent.

The ash in native peat, which renders it more or less impure, constitutes from 3 to 30 per cent of its dry weight and is traceable either to the plant cells or to the mineral matter carried in suspension or solution by the water in which the peat formed. The inorganic impurities of peat consist of silica, alumina, iron oxide, magnesia, lime, soda, potash, sulphuric acid, chlorine, and phosphoric acid. If the ash content exceeds 8 per cent, it is due to the mineral matter in the water that covered the peat during formation, and it usually consists of silica in the form of sand or silt or of alumina and silica in the form of clay. Mineral constituents other than silica and alumina in excess of 8 per cent are not common in peat and where found may be traced to the local ground and surface waters. The ash content of the best peats in the United States ranges from about 6 to 12 per cent, though many of the largest deposits in the Great Lakes area contain 15 per cent.

The following table shows the composition of the ash in three samples of typical New England peat[4]:

Analyses of the ash in Connecticut peat.

Inorganic impurities.	1	2	3
Sand	12.11	15.04	67.01
Carbonic acid	19.60	22.28	
Soluble silica	8.23	1.40	....
Iron and aluminum oxide	5.17	9.08	15.59
Magnesia	6.06	4.20	1.05
Lime	41.39	35.59	6.60
Soda	.58	.00	Trace.
Potash	.69	.80	3.46
Sulphuric acid	5.52	10.41	4.04
Chlorine	.15	.43	.70
Phosphoric acid	.50	.77	1.55
	100.00	100.00	100.00

If the inorganic impurities of decayed vegetation are much in excess of 30 per cent the material should be classed as muck rather than peat.

VALUE OF PEAT AS A FERTILIZER.

The value of peat in soil fertilization lies in its content of nitrogen and humus and in the beneficial mechanical effect it produces on certain lands. Black, well-decomposed peats are the most satisfactory ordinary fertilizers, for they are generally heavier and more compact and contain more nitrogen and less fibrous material than the brown peats. Raw, strongly acid peats, however, should be used in fertilizing soil intended for the growth of acid-tolerant crops.

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[4] Johnson, S. W., Peat and its uses, pp. 47–49, New York, 1866.

VALUE OF PEAT AS A FUEL.

The value of peat as fuel is dependent upon many factors, chief of which are the degree of decomposition, heating value, and ash content. Coarse-textured, fibrous peat is inferior for fuel to black, compact, thoroughly decomposed peat, except kinds that contain a very large proportion of ash. The heating value of good moisture-free peat, which ranges from 7,000 to 10,000 British thermal units per pound, is determined chiefly by its content of fixed carbon and ash. Though the ash is inert, it displaces an equal volume of combustible matter and absorbs heat in maintaining its temperature at the same degree as the accompanying carbon. Salt-marsh peat generally contains a large quantity of sodium chloride and other inorganic minerals, and is therefore of little value as fuel. The maximum quantity of ash that is usually considered allowable in peat for commercial use as fuel has been placed between 20 and 25 per cent, but if it exceeds 20 per cent of the total dry weight the peat is scarcely worth the labor of production. Though peat containing from 10 to 12 per cent of ash is good, in Ireland peat is not considered first-class fuel if the ash content exceeds 5 per cent.

The following table shows the calorific value of peat as used commercially compared with other fuels:

Comparative calorific value of peat and other fuels.

	British thermal units.
Wood	5,760
Air-dried cut peat	6,840
Air-dried machine peat	7,290
Lignite	7,500
Bituminous coal	14,000
Anthracite	13,000

In calorific value a ton of machine peat is equal to about 1.3 tons of wood, 0.5 ton of bituminous coal, and 0.6 ton of anthracite.

ANALYTICAL METHODS.

The chemical composition of peat, like that of coal, is usually determined by proximate and ultimate analyses. Percentages of moisture, volatile matter, fixed carbon, and ash are shown by the proximate analysis, and those of hydrogen, carbon, nitrogen, oxygen, sulphur, and ash by the standard ultimate analysis. The calorific value of the peat, both as received in the laboratory and moisture free, is then determined in calories, from which the value in British thermal units is calculated. The heating value of peat of any moisture content up to 30 per cent may be ascertained by deducting for each per cent of moisture 1 per cent from the calorific value determined as of water-free peat. A full description of the methods of making

chemical and calorimetric analyses of peat is given in Technical Paper 8 and Bulletin 16 of the United States Bureau of Mines.

The analyses of samples taken during the progress of field work for this report were made under the supervision of H. M. Cooper, of the United States Bureau of Mines. The samples were air-dried to about 50 per cent moisture in the field and sent to the laboratory in canvas bags.

ANALYSES.

The following tables give a large number of analyses of moisture-free peat made for this report, as well as of raw samples shipped to the laboratory in air-tight containers and tested in their native condition. Many of the tables were taken from Bureau of Mines Bulletin 16 and from reports issued by State geological surveys and other organizations.

CONNECTICUT.

Analyses of moisture-free peat and muck.

[H. M. Cooper, Bureau of Mines, analyst.]

Locality No.	County.	Analysis No.	Proximate.			Ultimate.					Calorific value.	
			Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
1	Fairfield.......	57	53.54	29.39	17.07	0.65	....	....	2.08	....	4,710	8,478
1	Do..........	58	52.52	34.63	12.85	.51	....	....	1.95	....	4,917	8,851
2	Hartford.......	59	44.18	4.09	51.73	.42	....	....	1.32	....	....	....
3	Middlesex......	60	40.04	1.71	58.25	.24	....	....	1.48	....	....	....
6	New Haven....	53	43.49	31.40	25.11	2.98	4.14	41.58	2.03	24.16	3,989	7,181
6	Do..........	53a	43.63	29.11	27.26	2.48	4.29	40.66	2.28	23.03	3,895	7,011
6	Do..........	53b	40.52	29.03	30.45	2.71	3.80	38.23	2.09	22.72	....	....
6	Do..........	53c	40.26	29.14	30.60	3.46	3.68	38.46	1.69	22.11	....	....
6	Do..........	53d	57.54	29.71	12.75	3.79	4.46	49.95	1.98	27.07	4,646	8,362
6	Do..........	54	46.05	23.38	30.57	2.06	....	....	2.08	....	....	....
7	Do..........	55	19.12	8.34	72.54	1.71	....	....	.54	....	....	....
8	Do..........	56	49.93	24.21	25.86	2.43	....	....	1.92	....	4,071	7,328
9	New Haven....	61	19.30	8.28	72.33	1.12	....	....	.75	....	....	....

Analyses of moisture-free peat.

[Furnished by E. A. Beals.]

Locality.	No. of analysis.	Area (acres).	Depth (feet).	Volatile.	Fixed carbon.	Ash.	Sulphur.	Nitrogen.	Calorific value (British thermal units).
NEW HAVEN COUNTY.									
Waterbury (1 mile west of)....	1	Small.	14	50.0	42.0	7.3	....	1.74	....
West of lighthouse south of New Haven..............	2	Small.	10	49.5	36.0	14.5	....	....	....
East of lighthouse south of New Haven..............	3	40	10	48.5	34.0	17.5	....	....	....
West Bog, 2½ miles from Waterbury................	4	60	14	51.75	39.0	9.7	....	....	....
Near East Haven............	5	....	12+	59.43	28.9	11.7	0.81	....	9,063
West of West Haven.........	6	35	12	49.0	35.0	16.0	....	....	....
Schmitz deposit near Waterbury....................	7	2	8	45.0	49.0	6.0	....	....	....
East Summit deposit near Waterbury................	8	3	....	49.5	43.0	7.5	....	....	....

Analyses of peat and muck. [a]

[F. M. Stanton, U. S. Geological Survey, analyst.]

Locality.	Laboratory No.	Condition of sample.[b]	Proximate.					Ultimate.				Air-drying loss.	Calorific value.	
			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories	British thermal units.
FAIRFIELD COUNTY.														
Bethel	6194	1	88.72	6.54	3.13	1.61	0.08					87.90	515	927
		2		57.98	27.75	14.27	.71						4,566	8,219
	6195	1	89.03	6.10	2.65	2.22	.11					88.30	481	866
		2		55.61	24.15	20.24	1.00						4,385	7,893
	6196	1	88.24	4.30	1.34	6.12	.12					87.60	300	540
		2		36.56	11.40	52.04	1.02						2,551	4,592
Brookfield	6182	1	59.01	24.71	12.25	4.03	.30					55.30	2,045	3,681
		2		60.28	29.89	9.83	.73						4,989	8,980
	6183	1	51.43	27.27	11.06	10.24	.53					46.40	2,121	3,818
		2		56.15	22.77	21.08	1.09						4,367	7,861
Danbury	6188	1	93.83	3.79	1.87	.51	.03					93.30	302	544
		2		61.43	30.30	8.27	.49						4,895	8,811
	6189	1	90.31	3.79	1.27	4.63	.08					89.10	284	511
		2		39.11	13.11	47.78	.83						2,931	5,276
New Fairfield	6203	1	9.63	54.65	27.79	7.93	.46					.00	4,367	7,861
		2		60.47	30.75	8.78	.51						4,832	8,698
	6204	1	9.42	46.23	23.87	20.48	.38					.00	3,819	6,874
		2		51.04	26.35	22.61	.42						4,216	7,589
	6205	1	24.90	42.27	18.93	13.90	.84					19.20	3,542	6,376
		2		56.28	25.21	18.51	1.12						4,716	8,489
Ridgefield	6200	1	87.90	7.24	4.02	.84	.04					87.10	600	1,080
		2		59.83	33.23	6.94	.33						4,959	8,926
	6201	1	91.23	5.15	2.98	.64	.03					90.80	421	758
		2		58.72	33.98	7.30	.34						4,800	8,640
	6202	1	82.15	11.52	5.49	.84	.08					81.10	909	1,636
		2		64.54	30.75	4.71	.45						5,092	9,166
Westport	6190	1	9.32	22.47	9.02	59.19	.66					5.00	1,725	3,105
		2		24.78	9.95	65.27	.73						1,902	3,424
	6191	1	12.70	55.61	27.57	4.12	.24					5.80	4,772	8,590
		2		63.70	31.58	4.72	.27						5,466	9,839
	6192	1	5.58	32.14	10.75	51.53	.40					.00	2,361	4,250
		2		34.04	11.38	54.58	.42						2,501	4,502
	6193	1	19.69	48.83	28.25	3.23	.19					14.00	4,273	7,691
		2		60.80	35.18	4.02	.24						5,321	9,578

LITCHFIELD COUNTY.														
Kent	6197	1	47.83	31.67	17.07	3.43	.29	....	....	....	....	43.50	2,534	4,561
		2	....	60.71	32.72	6.57	.56	....	....	....	....	....	4,857	8,743
	6198	1	12.10	52.58	28.10	7.22	.83	....	....	....	....	4.40	4,269	7,684
		2	....	59.82	31.97	8.21	.94	....	....	....	....	....	4,857	8,743
	6199	1	9.06	41.51	13.37	36.06	1.46	....	....	....	....	3.70	2,993	5,387
		2	....	45.65	14.70	39.65	1.61	....	....	....	....	....	3,291	5,924
Washington	6185	1	19.57	45.35	29.20	5.88	.86	....	....	....	....	11.20	4,324	7,608
		2	....	56.38	36.31	7.31	1.07	....	....	....	....	....	5,252	9,454
	6186	1	12.74	49.36	28.77	9.13	1.30	....	....	....	....	4.60	4,381	7,886
		2	....	56.57	32.97	10.46	1.49	....	....	....	....	....	5,021	9,038
	6187	1	7.53	21.23	10.99	60.25	2.92	....	....	....	....	2.80	1,643	2,957
		2	....	22.96	11.88	65.16	3.16	....	....	....	....	....	1,777	3,199
Woodstock	6165	1	80.35	3.91	1.38	14.36	.14	....	....	....	....	79.80	244	439
		2	....	19.90	7.02	73.08	.71	....	....	....	....	....	1,242	2,236
	6166	1	77.03	3.86	1.31	17.80	.11	....	....	....	....	76.40	229	412
		2	....	16.80	5.71	77.49	.48	....	....	....	....	....	997	1,796
	6167	1	88.06	3.86	1.68	6.40	.06	....	....	....	....	87.40	286	515
		2	....	32.33	14.07	53.60	.50	....	....	....	....	....	2,396	4,311
MIDDLESEX COUNTY.														
Chester	6171	1	84.83	3.70	1.75	9.72	.10	....	....	....	....	84.10	295	531
		2	....	24.39	11.54	64.07	.66	....	....	....	....	....	1,945	3,501
	6172	1	90.82	5.60	2.98	.60	.08	....	....	....	....	90.30	497	895
		2	....	61.60	32.46	6.54	.87	....	....	....	....	....	5,414	9,745
Clinton	6206	1	84.88	6.26	3.30	5.56	.50	....	....	....	....	84.30	493	887
		2	....	41.40	21.83	36.77	3.31	....	....	....	....	....	3,261	5,870
	6207	1	87.39	4.42	2.58	5.61	.27	....	....	....	....	86.90	336	605
		2	....	35.05	20.46	44.49	2.14	....	....	....	....	....	2,665	4,797
	6208	1	86.90	5.55	2.95	4.60	.38	....	....	....	....	86.30	417	751
		2	....	42.37	22.52	35.11	2.90	....	....	....	....	....	3,183	5,729
	6209	1	75.14	4.07	1.51	19.28	.08	....	....	....	....	74.50	236	425
		2	....	16.37	6.08	77.55	.32	....	....	....	....	....	949	1,708
	6210	1	84.09	3.65	1.75	10.51	.19	....	....	....	....	83.50	240	432
		2	....	22.94	11.00	66.06	1.19	....	....	....	....	....	1,508	2,714
	6211	1	86.66	5.20	3.22	4.92	.28	....	....	....	....	86.10	405	729
		2	....	38.98	24.14	36.88	2.10	....	....	....	....	....	3,035	5,463
	6212	1	83.80	4.70	2.43	9.07	.25	....	....	....	....	83.20	337	607
		2	....	29.01	15.00	55.99	1.54	....	....	....	....	....	2,080	3,744
	6213	1	85.60	6.32	3.97	4.11	.48	....	....	....	....	85.00	529	952
		2	....	43.89	27.57	28.54	3.33	....	....	....	....	....	3,674	6,613
	6214	1	85.18	6.32	3.74	4.76	.40	....	....	....	....	84.50	511	920
		2	....	42.65	25.23	32.12	2.70	....	....	....	....	....	3,448	6,206
Killingworth	6168	1	88.96	5.97	3.34	1.73	.05	....	....	....	....	88.40	530	954
		2	....	54.08	30.25	15.67	.45	....	....	....	....	....	4,801	8,642
	6169	1	88.46	3.93	1.80	5.81	.05	....	....	....	....	88.10	318	572
		2	....	34.06	15.59	50.35	.43	....	....	....	....	....	2,756	4,961
	6170	1	80.81	3.31	1.54	14.34	.06	....	....	....	....	80.10	237	427
		2	....	17.25	8.02	74.73	.31	....	....	....	....	....	1,235	2,223

[a] Davis, C. A., The uses of peat for fuel and other purposes: Bur. Mines Bull. 16, pp 186-189, 1911.

[b] 1, Native peat. 2, Moisture-free peat.

Analyses of peat and muck—Continued.

Locality.	Laboratory No.	Condition of sample.	Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
NEW HAVEN COUNTY.														
Beaver Marsh (near New Haven)	6155	1	91.20	6.61	1.84	0.35	0.02	10.59	5.00	0.13	83.91	90.10	472	850
		2		75.11	20.91	3.98	.23	5.23	56.82	1.48	32.26		5,364	9,655
	6156	1	93.10	4.14	2.13	.62	.03	10.70	3.69	.15	84.80	92.30	354	637
		2		60.00	30.87	9.13	.43	5.22	53.48	2.17	29.57		5,130	9,234
Cherry Hill Marsh	6157	1	86.98	4.91	2.21	5.90	.14	10.12	4.13	.25	79.46	85.70	408	734
		2		37.71	16.98	45.31	1.08	3.53	31.72	1.92	16.44		3,134	5,641
East Haven	6159	1	87.41	6.66	4.06	1.87	.15					86.00	602	1,084
		2	52.90	32.25	14.85	1.19							4,782	8,608
	6160	1	90.09	5.89	2.86	1.16	.08					89.20	499	898
		2		59.43	28.86	11.71	.81						5,035	9,063
	6161	1	84.69	4.66	1.63	9.02	.28					83.80	351	632
		2		30.44	10.64	58.92	1.83						2,293	4,127
New Haven	6158	1	83.91	4.88	2.76	8.45	.41					83.40	390	702
		2		30.33	17.15	52.52	2.55						2,424	4,363
	6184	1	87.77	4.36	2.54	5.33	.37					87.50	296	533
		2		35.65	20.77	43.58	3.03						2,420	4,356
NEW LONDON COUNTY.														
Franklin	6173	1	92.98	4.29	2.31	.42	.03					92.50	361	650
		2		61.11	32.91	5.98	.43						5,142	9,256
	6174	1	87.82	5.16	1.59	5.43	.08					87.20	370	666
		2		42.36	13.06	44.58	.66						3,038	5,468
	6175	1	87.23	4.13	2.12	6.52	.15					86.40	338	608
		2		32.34	16.60	51.06	1.17						2,647	4,765
Stonington	6180	1	88.55	6.03	3.00	2.42	.09					87.90	523	941
		2		52.66	26.20	21.14	.79						4,568	8,222
	6181	1	87.87	7.42	3.83	.88	.05					87.20	674	1,213
		2		61.17	31.58	7.25	.41						5,556	10,001
Thompson	6162	1	92.25	4.51	2.52	.72	.08					91.60	394	709
		2		58.19	32.52	9.29	1.03						5,084	9,151
	6163	1	85.66	8.52	4.54	1.28	.10					85.00	768	1,382
		2		59.41	31.66	8.93	.70						5,356	9,641
	6164	1	88.64	4.27	2.00	5.09	.11					88.30	336	605
		2		37.59	17.60	44.81	.96						2,958	5,324
WINDHAM COUNTY.														
Hampton		1	88.52	3.33	1.20	6.95	.05					87.80	245	441
	6176	2		29.01	10.45	60.54	.44						2,134	3,841
		1	91.10	5.19	2.99	.72	.07					90.40	446	803
	6177	2		58.31	33.60	8.09	.79						5,011	9,020
		1	91.60	4.95	2.78	.67	.06					90.90	428	770
	6178	2		58.93	33.09	7.98	.71						5,095	9,171
		1	91.02	5.37	3.00	.61	.11					90.30	455	819
	6179	2		59.80	33.41	6.79	1.22						5,067	9,121

Analyses of peat and muck.[a]

[F. M. Stanton, U. S. Geological Survey, analyst.]

Locality.	Laboratory No.	Condition of sample.[b]	Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
CITRUS COUNTY.														
Inverness, half a mile northeast of (T. 19 S., R. 20 E.)	c 7205	1	89.49	......	......	......	......	......	......	......	......	88.60	......	......
	d 7204	1	28.14	43.24	19.73	8.89	0.72	......	......	......	......	21.40	3,725	6,705
		2	......	60.17	27.46	12.37	1.00	......	......	......	......	......	5,184	9,331
CLAY COUNTY.														
Green Grove Springs, about 3 miles southeast of (T. 6 S., R. 26 or 27 E.)	d 7106	1	9.59	6.31	.67	83.43	.08	......	......	0.12	......	6.50	......	......
		2	......	6.98	.74	92.28	1.04	......	......	.13	......	......	......	......
DADE COUNTY.														
Everglades, south edge of	d 7560	1	41.92	6.63	22.38	29.07	.05	......	......	......	......	40.90	388	698
		2	......	11.42	38.53	50.05	.09	......	......	......	......	......	668	1,202
Fort Lauderdale, about 10 miles west of	c 7638	1	91.26	......	......	......	......	......	......	......	......	90.40	......	......
	d 7637	1	61.99	20.10	11.87	6.04	.16	......	......	......	......	57.90	1,746	3,143
		2	......	52.88	31.23	15.89	.42	......	......	......	......	......	4,594	8,269
Miami, 1¼ miles northwest of (sec. 35, T. 53 S., R. 41 E.)	c 7604	1	82.75	......	......	......	......	......	......	......	......	81.90	......	......
	d 7603	1	66.59	11.52	8.69	13.20	.89	......	......	......	64.30	......	......	......
		2	......	34.48	26.01	39.51	2.66	......	......	......	......	......	......	......
Miami, 5 miles west of (T. 53 S., R. 41 E.)	c 7602	1	91.63	......	......	......	......	......	......	......	......	90.90	......	......
	d 7601	1	76.31	11.65	7.13	1.91	.13	......	......	......	......	77.40	1,114	2,005
		2	......	56.31	34.46	9.23	.63	......	......	......	......	......	5,384	9,691
Paradise Key, northwest of	c 7559	1	89.41	......	......	......	......	......	......	......	......	88.70	......	......
DE SOTO COUNTY.														
Nocatee, west of	c 7320	1	87.99	......	......	......	......	......	......	......	......	87.20	......	......
	d 7321	1	14.17	51.32	26.18	8.33	.31	......	......	......	......	5.90	4,489	8,080
		2	......	59.79	30.50	9.71	.36	......	......	......	......	......	5,230	9,414
DUVAL COUNTY.														
Bayard	6028	1	73.10	14.00	8.06	4.85	1.06	9.27	13.37	.53	70.92	69.90	1,283	2,309
		2	......	52.04	29.93	18.03	3.94	4.28	49.70	1.97	22.08	......	4,770	8,586

[a] Davis, C. A., The uses of peat for fuel and other purposes: Bur. Mines Bull. 16, pp. 189–192, 1911.

[b] 1, Native peat. 2, Moisture-free peat.

[c] Bottle sample.

[d] Sack sample.

Analyses of peat and muck—Continued.

Locality.	Laboratory No.	Condition of sample.	Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
DUVAL COUNTY—continued.														
Bayard	6027	1	73.56	14.44	8.11	3.89	1.08	9.34	13.84	0.51	71.34	67.40	1,295	2,331
		2	......	54.61	30.68	14.71	4.08	4.43	52.34	1.93	22.51	......	4,898	8,816
	6030	1	75.29	13.00	7.60	4.11	1.02	9.42	12.70	.48	72.27	70.80	1,195	2,151
		2	......	52.61	30.76	16.63	4.13	4.25	51.40	1.94	21.65	......	4,836	8,705
	6029	1	71.14	13.98	7.47	7.41	1.05	8.96	13.21	.48	68.89	63.20	1,248	2,246
		2	......	48.44	25.88	25.68	3.64	3.67	45.77	1.66	19.58	......	4,324	7,783
Bayard, 5 miles west of (sec. 28, T. 4 S., R. 27 E.)	[a] 7115	1	89.27	......	......	......	......	......	......	......	......	89.00	......	......
	[b] 7114	1	50.19	27.10	15.86	6.85	1.38	......	......	.94	......	45.50	2,517	4,531
		2	......	54.41	31.84	13.75	2.77	......	......	1.89	......	......	5,053	9,095
	[b] 7104	1	34.82	36.63	21.11	7.44	2.04	......	......	1.69	......	28.00	3,279	5,902
		2	......	56.20	32.39	11.41	3.13	......	......	2.59	......	......	5,031	9,056
HERNANDO COUNTY.														
Brooksville, 2 miles southeast of (T. 22 S., R. 19 E.)	[a] 7262	1	70.04	......	......	......	......	......	......	......	......	69.10	......	......
	[b] 7263	1	64.75	8.30	4.58	22.37	.05	......	......	......	......	63.30	659	1,186
		2	......	23.55	12.99	63.46	.14	......	......	......	......	......	1,870	3,366
Istachatta, near (T. 21 S., R. 20 E.)	[a] 7203	1	84.29	......	......	......	......	......	......	......	......	83.00	......	......
	[b] 7202	1	18.12	46.19	22.98	12.71	.53	......	......	......	......	9.80	4,804	8,647
		2	......	56.41	28.07	15.52	.65	......	......	......	......	......	5,867	10,561
LAKE COUNTY.														
Clermont, 2 miles northwest of (sec. 14, T. 22 S., R. 25 E.)	[a] 7633	1	95.00	......	......	......	......	......	......	......	......	94.60	......	......
	[b] 7632	1	79.69	13.77	6.23	.31	.08	......	......	......	......	78.00	1,226	2,207
		2	......	67.80	30.67	1.53	.39	......	......	......	......	......	6,036	10,865
	[a] 7635	1	91.89	......	......	......	......	......	......	......	......	91.20	......	......
	[b] 7634	1	82.12	11.75	5.72	.41	.05	......	......	......	......	80.40	1,048	1,886
		2	......	65.72	31.99	2.29	.28	......	......	......	......	......	5,860	10,548
Eldorado, 1 mile northeast of (T. 19 S., R. 25 E.)	[a] 7254	1	91.74	......	......	......	......	......	......	......	......	91.40	......	......
	[b] 7255	1	71.35	12.39	5.00	11.26	.17	......	......	......	......	70.10	1,011	1,820
		2	......	43.25	17.45	39.30	.59	......	......	......	......	......	3,529	6,352
	[a] 7256	1	90.54	......	......	......	......	......	......	......	......	90.00	......	......
	[b] 7257	1	72.9	17.98	7.76	1.37	.08	......	......	......	......	71.40	1,431	2,576
		2	......	66.32	28.63	5.05	.29	......	......	......	......	......	5,279	9,502
Eustis, 3 miles north of (T. 18 S., R. 26 E.)	[a] 7113	1	75.66	......	......	......	......	......	......	......	......	75.10	......	......
	[b] 7112	1	5.59	11.11	6.12	77.18	.07	......	......	1.75	......	3.70	......	......
		2	......	11.77	6.48	81.75	.07	......	......	1.85	......	......	......	......
Leesburg, just east of (T. 19 S., R. 24 E.)	[a] 7258	1	93.47	......	......	......	......	......	......	......	......	73.10	......	......
	[b] 7259	1	84.39	7.60	2.57	5.44	.19	......	......	.41	......	83.50	587	1,057
		2	......	48.69	16.46	34.85	1.21	......	......	2.62	......	......	3,760	6,768

	[a] 7260	1	95.16	....	....	....	....	....	....	....	....	94.90	....	....
	[b] 7261	1	69.89	19.86	7.78	2.47	0.11	....	....	....	....	68.40	1,554	2,797
		2	....	65.96	25.84	8.20	.37	....	....	....	....	....	5,161	9,290
	[b] 7310	1	10.68	52.72	29.28	64.30	.54	....	....	....	....	3.70	4,660	8,388
		2	....	59.03	32.77	35.70	.60	....	....	....	....	....	5,217	9,391
	[b] 7311	1	3.24	8.26	5.51	82.99	....	....	....	....	....	.90	....	....
		2	....	8.54	5.69	85.77	....	....	....	....	....	....	....	....
Tavares, 3 miles east of (T. 19 S., R. 26 E.)........	[a] 7109	1	86.03	....	....	....	....	....	....	....	....	85.50	....	....
	[b] 7108	1	69.15	16.54	7.54	6.77	.21	....	....	0.78	....	67.00	838	1,508
		2	....	53.61	24.45	21.94	.68	....	....	2.53	....	....	2,716	4,889
	[a] 7111	1	96.13	....	....	....	....	....	....	....	....	95.90	....	....
	[b] 7110	1	26.21	39.90	20.07	13.82	.55	....	....	1.44	....	21.90	3,700	6,660
		2	....	54.07	27.20	18.73	.75	....	....	1.95	....	....	5,014	9,025
Tavares, 1½ miles southwest of (T. 19 S., R. 26 E.)........	[a] 7369	1	92.44	....	....	....	....	....	....	....	....	91.90	....	....
	[b] 7370	1	67.91	16.69	10.20	5.20	.13	....	....	....	....	65.50	1,593	2,867
		2	....	52.01	31.79	16.20	.41	....	....	....	....	....	4,964	8,935
	[b] 7367	1	95.52	....	....	....	....	....	....	....	....	94.90	....	....
	[a] 7368	1	66.90	16.01	10.34	6.75	.09	....	....	....	....	64.20	1,563	2,818
		2	....	48.37	31.24	20.39	.27	....	....	....	....	....	4,722	8,500
West Apopka, just north of (T. 21 S., R. 26 E.)........	[a] 7318	1	92.24	....	....	....	....	....	....	....	....	91.80	....	....
	[b] 7319	1	72.49	18.23	7.71	1.57	.11	....	....	....	....	70.90	1,556	2,801
		2	....	66.27	28.02	5.71	.40	....	....	....	....	....	5,656	10,181
LEON COUNTY.														
Tallahassee, 5 miles west-northwest of (sec. 29, T. 1 N., R. 1 W.)	[b] 7105	1	54.39	29.78	13.88	1.95	.22	....	....	1.05	....	51.60	2,469	4,444
		2	....	65.29	30.43	4.28	.48	....	....	2.30	....	....	5,413	9,743
	[b] 7107	1	66.23	21.30	9.92	2.55	.08	....	....	.88	....	64.20	1,771	3,188
		2	....	63.07	29.38	7.55	.24	....	....	2.61	....	....	5,244	9,439
MANATEE COUNTY.														
Peaty Prairie, about 2 miles south of (Manatee)........	[a] 7691	1	56.38	....	....	....	....	....	....	....	....	55.00	....	....
OSCEOLA COUNTY.														
Ashton, 1 mile north of (T. 26 S., R. 31 E.)........	[a] 7155	1	86.80	....	....	....	....	....	....	....	....	86.20	....	....
	[b] 7154	1	76.48	10.86	7.97	4.69	.09	....	....	....	....	75.80	1,105	1,989
		2	....	46.17	33.89	19.94	.38	....	....	....	....	....	4,698	8,456
POLK COUNTY.														
Auburndale, 2 miles west of........	[a] 7199	1	94.32	....	....	....	....	....	....	....	....	93.90	....	....
	[b] 7198	1	14.30	47.91	31.06	6.73	.35	....	....	....	....	5.80	4,561	8,210
		2	....	55.90	36.25	7.85	.41	....	....	....	....	....	5,322	9,580
Bartow Junction and Auburndale, halfway between (T. 28 S., R. 25 or 26 E.)........	[a] 7167	1	95.51	....	....	....	....	....	....	....	....	95.20	....	....
	[b] 7166	1	43.55	34.43	19.66	2.36	.17	....	....	....	....	38.90	3,269	5,884
		2	....	60.99	34.83	4.18	.30	....	....	....	....	....	5,791	10,424
	[a] 7169	1	92.68	....	....	....	....	....	....	....	....	92.10	....	....
	[b] 7168	1	54.65	25.98	14.52	4.85	.18	....	....	....	....	50.60	2,359	4,246
		2	....	57.29	32.02	10.69	.40	....	....	....	....	....	5,202	9,364

[a] Bottle sample.

[b] Sack sample.

Analyses of peat and muck—Continued.

Locality.	Laboratory No.	Condition of sample.	Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
POLK COUNTY—continued.														
Florence Villa, half a mile north of (T. 28 S., R. 26 E.)	a 7165	1	83.82	......	......	......	......	......	......	......	......	82.70	......	......
	b 7164	1	38.79	23.42	15.21	22.58	0.17	......	......	......	......	33.70	2,163	3,893
		2	......	38.26	24.85	36.89	.28	......	......	......	......	......	3,534	6,361
Lakeland, 2 miles east of (T. 28 S., R. 24 E.)	a 7201	1	94.40	......	......	......	......	......	......	......	......	94.00	......	......
	b 7200	1	13.37	55.07	28.92	2.64	.34	......	......	......	......	5.40	5,072	9,130
		2	......	63.57	33.38	3.05	.39	......	......	......	......	......	5,855	10,539
PUTNAM COUNTY.														
Palatka, 1 mile south of (T. 10 S., R. 27 E.)	a 7151	1	90.85	......	......	......	......	......	......	......	......	90.30	......	......
	b 7150	1	80.78	9.72	6.32	3.18	.40	......	......	......	......	79.40	923	1,661
		2	......	50.57	32.88	16.55	2.08	......	......	......	......	......	4,802	8,644
	a 7153	1	86.94	......	......	......	......	......	......	......	......	86.30	......	......
	b 7152	1	77.67	11.79	8.55	1.99	.21	......	......	......	......	76.80	1,169	2,104
		2	......	52.80	38.29	8.91	.94	......	......	......	......	......	5,235	9,423
SANTA ROSA COUNTY.														
Milton, near (T. 1 N., R. 28 W.)	a 7021	1	71.63	......	......	......	......	......	......	......	......	70.70	......	......
	b 7022	1	58.14	5.63	2.85	33.38	.35	......	......	......	......	56.50	604	1,087
		2	......	13.45	6.81	79.74	.84	......	......	......	......	......	1,443	2,597
	a 7023	1	83.50	......	......	......	......	......	......	......	......	82.90	......	......
	b 7024	1	68.89	6.36	3.70	21.05	.66	......	......	......	......	67.80	501	902
		2	......	20.44	11.90	67.66	2.12	......	......	......	......	......	1,610	2,898
SUMTER COUNTY.														
Lake Panasoffkee, south end of	a 7697	1	86.30	......	......	......	......	......	......	......	......	85.20	......	......
	a 7695	1	93.17	......	......	......	......	......	......	......	......	92.30	......	......
	a 7693	1	93.60	......	......	......	......	......	......	......	......	92.80	......	......

[a] Bottle sample.

[b] Sack sample.

ILLINOIS.

Analyses of moisture-free peat and muck.

[H. M. Cooper, Bureau of Mines, analyst.]

County.	Locality No.	Analysis No.	Proximate.			Ultimate.		Calorific value.	
			Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Nitrogen.	Calories.	British thermal units.
Kankakee	2	317	41.19	29.22	29.59	2.39	3.03	3,786	6,814
Lake	3	300	61.20	23.66	15.14	1.14	3.84	4,528	8,150
Do	4	301	33.27	19.33	47.40	2.26	2.18	....	....
Do	5	302	57.47	20.79	21.74	2.43	2.85	4,309	7,756
Do	6	303	67.63	23.25	91.12	.52	2.52	4,909	8,837
Do	7	304	34.57	23.46	41.97	.67	2.45	....	....
Do	8	305	68.15	11.24	20.61	1.20	3.18	4,208	7,575
Do	9	306	58.67	30.72	10.61	.66	2.88	4,776	8,596
Mason and Tazewell	13	313	63.99	9.44	26.57	1.21	2.24	3,922	7,060
Do	14	314	34.83	26.05	39.12	.38	1.92	....	....
Do	14	315	62.70	2.96	34.34	.30	2.97	....	....
Do	14	316	37.17	27.48	35.35	.41	2.42	....	....
Whiteside	15	307	65.65	6.37	27.98	.36	2.66	3,759	6,766
Do	15	308	63.18	23.04	13.78	.27	3.23	4,564	8,215
Do	15	309	61.51	23.86	14.63	.27	3.30	4,609	8,296
Do	16	310	62.01	21.36	16.63	.49	2.52	4,702	8,464
Do	16	311	50.52	6.48	43.00	.39	2.05	....	....
Do	16	312	32.20	17.78	50.02	.56	1.48	....	....

INDIANA.

Analyses of moisture-free peat.

[H. M. Cooper, Bureau of Mines, analyst.]

County.	Locality No.	Analysis No.	Proximate.			Ultimate.		Calorific value.	
			Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Nitrogen.	Calories.	British thermal units.
Allen	1	338	32.81	33.55	33.64	1.07	2.88	....	....
Do	1	339	41.65	39.48	18.87	.85	3.54	4,326	7,786
Do	1	340	40.17	41.73	18.10	.89	3.17	4,195	7,551
Dekalb	2	343	43.72	50.94	5.34	.30	1.77	4,865	8,757
Do	3	341	45.79	42.13	12.08	.73	3.00	4,673	8,412
Elkhart	4	332	35.67	39.30	25.03	.63	2.84	4,015	7,227
Do	5	333	40.93	48.61	10.46	.41	2.28	4,708	8,475
Do	6	337	44.17	44.84	10.99	.32	3.29	4,759	8,566
Fulton	7	328	40.78	48.23	10.99	.24	2.98	4,938	8,888
Do	8	329	42.33	48.85	8.82	.17	2.64	5,074	9,134
Jasper	9	321	42.83	41.02	16.15	3.69	3.34	4,709	8,477
Kosciusko	10	330	44.65	46.52	8.83	.27	2.47	4,887	8,796
Do	10	331	55.40	35.30	9.30	.28	2.69	4,554	8,198
Marshall	11	325	46.88	44.65	8.47	.34	2.40	4,819	8,675
Do	12	326	40.91	50.92	8.17	.27	2.25	5,152	9,273
Do	12	327	33.81	56.98	9.21	.26	2.35	5,166	9,299
Noble	13	342	45.07	47.37	7.56	.35	2.81	4,867	8,761
Pulaski	14	322	40.04	43.45	16.51	.96	2.91	4,851	8,731
St. Joseph	15	324	43.53	44.59	11.88	1.61	2.86	4,628	8,331
Do	16	334	33.68	41.10	25.22	.33	2.29	....	....
Do	16	335	49.26	25.22	25.52	.29	2.20	....	....
Do	16	336	45.99	35.75	18.26	.31	2.92	4,397	7,915
Starke	17	318	60.87	24.42	14.71	.35	3.25	4,785	8,613
Do	17	319	61.07	24.19	14.74	.34	2.71	7,446	8,543
Do	18	320	61.04	26.86	12.10	.83	3.26	4,699	8,459
Do	19	323	44.33	41.63	14.04	.39	2.61	4,955	8,919
Steuben	20	344	41.07	46.49	12.44	.43	3.66	4,879	8,782
Do	21	345	38.05	48.69	13.26	.39	3.29	4,815	8,667
Do	21	346	31.73	57.92	10.35	.43	3.76	4,957	8,922

Analyses of air-dried peat.[a]

[R. E. Lyons, University of Indiana, analyst.]

Locality.				Volatile matter.	Fixed carbon.	Coke.	Ash.	Sulphur.[b]	Nitrogen.
County.	Section.	T. N.	R. E.						
Dekalb	9	33	12	73.31	22.53	26.67	4.14	0.74	2.58
Marshall	10, 11	33	1	70.97	19.08	29.09	10.01	.83	3.91
Starke	10	33	3	62.43	24.30	37.55	13.25	.96	2.96
St. Joseph	28,33,34	36	2	70.21	23.45	29.78	6.33	.87	2.22
Do	3	36	1	65.52	20.65	34.47	13.82	1.33	3.31

[a] Taylor, A. E., The peat deposits of northern Indiana: Indiana Dept. Geology and Nat. Res. Thirty-first Ann. Rept., p. 112, 1906.

[b] The samples were oven dried before the sulphur content was determined.

Fuel value of peat oven-dried at 105° C.[a]

[R. E. Lyons, University of Indiana, analyst.]

Locality.				Sample No.	Calorific value.	
County.	Section.	T. N.	R.		Calories.	British thermal units.
Dekalb	9	33	12 E.	1	5,685	10,233
Elkhart	4	36	5 E.	10	4,799	8,638
Do	10, 11	36	6 E.	11	4,006	7,211
Do	26, 27	35	5 E.	12	4,229	7,613
Do	18	38	6 E.	13	5,349	9,629
Jasper	12, 13, 14	30	6 W.	27	4,596	8,273
Kosciusko	11, 12, 13	31	6 E.	8	5,398	9,716
Do	32, 33	33	6 E.	9	3,405	6,128
Lagrange	2, 11, 12	36	8 E.	3	4,730	8,511
Do	4, 9	37	9 E.	4	4,958	8,924
Lake	34, 35, 36	35	9 W.	29	4,851	8,731
Marshall	10, 11	33	1 E.	19	5,526	9,946
Do	1	34	2 E.	20	4,721	8,498
Do	10	34	1 E.	21	5,815	10,466
Newton	32, 33	31	8 W.	28	5,019	9,036
Noble	28, 29	33	9 E.	5	5,742	10,336
Do	18	33	11 E.	6	5,121	9,217
Porter	1, 2, 3	37	5 W.	26	3,131	5,635
Pulaski	9	31	1 W.	23	5,430	9,775
Do	7, 8, 9	31	3 W.	24	5,036	9,065
Do	3, 9, 10, 11	31	4 W.	14	4,707	9,065
St. Joseph	28, 33, 34	36	2 E.	15	5,467	9,840
Do	3	36	1 E.	16	5,013	9,024
Do	11, 12	37	1 E.	17	4,724	8,504
Do	16	37	2 E.	18	4,584	8,236
Do	20	37	2 E.	22	4,718	8,491
Starke	10	32	3 E.	2	5,503	9,906
Steuben	34	37	12 E.	7	5,234	9,423
Whitley	30	31	10 E.		2,523	4,542

[a] Taylor, A. E., op. cit., p. 111.

IOWA.

Analyses of air-dried peat.[a]

Locality.		Laboratory No.	Proximate.				Calorific value (British thermal units).
County.	Township.		Moisture.	Volatile and combustible matter.	Fixed carbon.	Ash.	
Cerro Gordo	Clear Lake	594	7.30	50.71	17.10	24.89	6,452
Do.	Grant	595	7.97	52.94	16.60	22.49	7,122
Do.	Lake	598	11.81	45.03	23.51	19.66	6,125
Do.	Mount Vernon	596	7.99	52.61	15.47	23.93	6,904
Franklin	Morgan	354	8.66	52.47	15.38	23.49	7,699
Hancock	Crystal	647	7.55	54.57	15.67	22.21	7,278
Kossuth	Sherman	636	10.51	51.61	13.80	24.09	6,811
Winnebago	Center	514	10.07	55.10	14.65	20.18	7,418
Do.	do.	499	10.85	50.71	13.29	25.15	7,169
Do.	Norway	597	11.91	50.23	17.02	20.84	6,966
Do.	Mount Valley	563	5.89	63.59	16.39	14.13	8,431
Worth	Bristol	489	19.74	49.60	12.18	18.48	6,624
Do.	do	490	19.61	48.07	13.49	18.83	6,764
Do.	Hortland	533	11.27	51.18	13.32	24.23	6,951
Do.	Silver Lake	492	18.26	49.57	13.03	19.14	6,889

[a] Beyer, S. W., Peat deposits in Iowa: Iowa Geol. Survey, vol. 19, pp. 725–730, 1908.

MAINE.

Analyses of peat and muck.[a]

[F. M. Stanton, U. S. Geological Survey, analyst.]

Locality.	Laboratory No.	Condition of sample.[b]	Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
ANDROSCOGGIN COUNTY.														
Greene, near	5895	1	86.52	7.55	4.22	1.71	0.08	....	....	0.24	....	85.00	655	1,179
		2	....	56.01	31.30	12.69	.59	....	....	1.78	....	....	4,859	8,746
Lewiston, 2 miles east of (Garcelon Bog)	5863	1	82.71	....	....	1.16	.02	....	....	.20	....	80.80	892	1,606
		2	....	....	....	6.71	.12	....	....	1.16	....	....	5,159	9,286
Lewiston, 2 miles east of	5897	1	86.98	7.84	4.40	.78	.02	....	....	.13	....	84.20	682	1,228
		2	....	60.22	33.79	5.99	.15	....	....	1.00	....	....	5,238	9,428
	5894	1	85.91	8.43	4.37	1.29	.07	....	....	.23	....	84.60	715	1,287
		2	....	59.83	31.01	9.16	.50	....	....	1.63	....	....	5,057	9,135
Lewiston, 2 miles east of (machine peat)	5865	1	65.39	....	....	1.55	.17	....	....	.46	....	60.40	1,127	2,029
		2	....	....	....	4.48	.49	....	....	1.33	....	....	3,256	5,861
Lewiston, 4 miles east of (bog south of No Name Pond)	5864	1	87.55	....	....	.67	.02	....	....	.14	....	86.10	610	1,098
		2	....	....	....	5.38	.16	....	....	1.12	....	....	4,900	8,820
Lewiston, 4 miles east of	5866	1	88.67	5.83	2.95	2.55	.02	....	....	.13	....	87.60	460	828
		2	....	51.46	26.03	22.51	.18	....	....	1.15	....	....	4,060	7,308
	5896	1	85.49	8.01	3.99	2.51	.05	....	....	.20	....	84.80	634	1,141
		2	....	55.20	27.50	17.30	.34	....	....	1.38	....	....	4,369	7,864
AROOSTOOK COUNTY.														
Crystal, 2 miles southwest of	5912	1	85.02	....	....	1.41	.04	....	....	.23	....	83.61	763	1,373
		2	....	....	....	9.41	.27	....	....	1.54	....	....	5,093	9,167
Houlton, 1 mile southwest of	5913	1	87.47	....	....	.75	.02	....	....	.16	....	86.30	678	1,220
		2	....	....	....	5.99	.16	....	....	1.28	....	....	5,411	9,740
Sherman, near	5914	1	86.18	8.27	3.98	1.57	.10	....	....	.28	....	82.80	719	1,294
		2	....	59.84	28.80	11.36	.72	....	....	2.03	....	....	5,203	9,365
CUMBERLAND COUNTY.														
Cape Elizabeth, near	5861	1	85.87	8.12	4.25	1.76	.14	....	....	.26	....	84.00	701	1,262
		2	....	57.47	30.07	12.46	.99	....	....	1.84	....	....	4,961	8,930
	5995	1	84.44	8.93	4.95	1.68	.17	....	....	....	....	82.00	....	....
		2	....	57.39	31.81	10.80	.09	....	....	....	....	....	....	....
Cumberland Mills, 5½ miles north of	5844	1	91.00	5.41	2.60	.99	.01	....	....	.07	....	89.20	419	754
		2	....	60.11	28.89	11.00	.11	....	....	.78	....	....	4,656	8,381
	5836	1	89.59	6.42	3.27	.72	.01	....	....	.08	....	88.30	521	938
		2	....	61.67	31.41	6.92	.10	....	....	.77	....	....	5,005	9,009

HANCOCK COUNTY.														
Bucksport	5888	1	86.80	...	...	.73	.02	...	...	...	...	86.00	672	1,210
		2	...	...	...	5.21	.14	...	...	...	...	...	4,800	8,640
Nicolin station, one-third of a mile north of	5837	1	86.13	8.13	4.84	.90	.02	...	...	.13	...	84.40	711	1,280
		2	...	58.63	34.88	6.49	.14	...	...	.94	...	...	5,126	9,227
KENNEBEC COUNTY.														
Augusta	5881	1	80.64	...	...	6.38	.16	...	...	.31	...	78.60	756	1,361
		2	...	...	...	32.96	.83	...	...	1.60	...	...	3,906	7,029
Benton Falls, 2½ miles southeast of	5885	1	77.11	9.93	6.34	6.62	.17	...	...	.45	...	74.90	911	1,640
		2	...	43.38	27.70	28.92	.74	...	...	1.97	...	...	3,960	7,164
Oakland, 3 miles north of (Martin Stream Bog)	5915	1	82.84	10.83	5.49	.84	.03	...	...	.19	...	81.40	927	1,669
		2	...	63.11	31.99	4.90	.17	...	...	1.11	...	...	5,402	9,724
West Sidney, near (Great Sidney Bog)	5978	1	87.59	8.69	3.07	.65	.02	10.38	6.22	.13	82.60	86.70	584	1,051
		2	...	70.02	24.74	5.24	.16	5.24	50.12	1.06	38.19	...	4,706	8,471
West Sidney, west of (Great Sidney Bog)	5979	1	87.62	8.06	3.05	1.27	.01	...	...	...	...	86.40	...	...
		2	...	65.11	24.63	10.26	.81	...	...	...	...	...	...	...
West Sidney	5980	1	89.14	7.39	2.93	.54	.01	...	...	...	...	88.10	...	...
		2	...	68.05	26.98	4.97	.92	...	...	...	...	...	...	...
	5981	1	88.61	7.51	3.17	.71	.03	...	...	...	...	87.50	...	...
		2	...	65.93	27.84	6.23	.26	...	...	...	...	...	...	...
	5982	1	84.92	10.25	4.14	.69	.02	...	...	...	...	83.40	...	...
		2	...	67.97	27.45	4.58	.13	...	...	...	...	...	...	...
	5983	1	87.49	8.46	3.57	.48	.02	10.38	6.87	.16	82.09	86.30	667	1,201
		2	...	67.63	28.53	3.84	.16	5.28	54.92	1.28	34.52	...	5,332	9,598
	5984	1	82.04	11.19	5.45	1.32	.13	...	...	...	...	79.60	...	...
		2	...	62.30	30.35	7.35	.72	...	...	...	...	...	...	...
Winslow	5882	1	85.43	...	...	1.00	.06	...	...	.22	...	81.70	746	1,343
		2	...	...	...	6.86	.41	...	...	1.51	...	...	5,120	9,216
	5883	1	83.53	...	...	3.63	.11	...	...	.34	...	81.70	694	1,249
		2	...	...	...	22.04	.67	...	...	2.06	...	...	4,214	7,585
KNOX COUNTY.														
Rockland, 2½ miles northwest of	5838	1	90.82	6.07	2.73	.38	.02	...	...	.08	...	89.80	455	819
		2	...	66.12	29.74	4.14	.22	...	...	.87	...	...	4,956	8,921
	5840	1	91.93	...	...	1.59	.04	...	...	.25	...	91.00	353	635
		2	...	...	...	19.70	.50	...	...	3.10	...	...	4,374	7,873
OXFORD COUNTY.														
Hartford, north of	5867	1	85.31	8.35	2.81	3.53	.04	...	...	.20	...	81.80	637	1,147
		2	...	56.84	19.13	24.03	.27	...	...	1.36	...	...	4,336	7,805
Norway, 3½ miles north of	5862	1	79.95	11.56	6.80	1.69	.07	...	...	.31	...	78.40	990	1,782
		2	...	57.66	33.91	8.43	.35	...	...	1.55	...	...	4,938	8,888
PENOBSCOT COUNTY.														
Alton, 1½ miles north of	5839	1	90.89	...	...	.76	.01	...	...	.08	...	87.90	430	467
		2	...	...	...	8.34	.11	...	...	.88	...	...	4,720	8,497
Bangor, 10 miles north of	5893	1	86.95	...	...	1.10	.04	...	...	.26	...	86.00	670	1,206
		2	...	...	...	8.43	.31	...	...	1.99	...	...	5,134	9,241
	5890	1	87.05	...	...	2.89	.08	...	...	.26	...	86.40	585	1,063
		2	...	...	...	18.46	.62	...	...	2.01	...	...	4,517	8,1313

[a] Davis, C. A., The uses of peat for fuel and other purposes: Bur. Mines Bull. 16, pp. 192–196, 1911.

[b] 1, Native peat. 2, Moisture-free peat.

Analyses of peat and muck—Continued.

Locality.	Laboratory No.	Condition of sample.	Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
PENOBSCOT COUNTY—continued.														
Etna, 1 mile west of	5891	1	84.68	....	....	1.33	0.10	....	....	0.35	....	83.60	779	1,402
		2	....	....	....	8.68	.65	....	....	2.28	....	....	5,085	9,153
Hermon Center, west of	5902	1	86.48	....	....	1.50	.07	....	....	.29	....	85.60	678	1,220
		2	....	....	....	11.09	.52	....	....	2.14	....	....	5,015	9,027
	5892	1	88.23	....	....	1.15	.06	....	....	.25	....	87.00	587	1,057
		2	....	....	....	9.77	.51	....	....	2.12	....	....	4,987	8,977
Hermon Pond, southwest of	5916	1	89.01	6.93	3.43	.63	.04	....	....	.23	....	86.80	588	1,058
		2	....	63.06	31.21	5.73	.36	....	....	2.09	....	....	5,350	9,630
Newport, three-fourths of a mile east of	5889	1	85.59	....	....	1.09	.02	....	....	.17	....	84.80	736	1,325
		2	....	....	....	7.56	.14	....	....	1.18	....	....	5,108	9,194
Spragues, near	5841	1	88.34	....	....	.84	.02	....	....	.14	....	85.00	597	1,075
		2	....	....	....	7.20	.17	....	....	1.20	....	....	5,120	9,216
SOMERSET COUNTY.														
Oakland, 4 miles north of	5884	1	83.64	....	....	.80	.03	....	....	.21	....	82.20	872	1,570
		2	....	....	....	4.89	.18	....	....	1.28	....	....	5,330	9,594
	5880	1	83.66	....	....	4.09	.11	....	....	.26	....	82.30	667	1,201
		2	....	....	....	25.03	.67	....	....	1.59	....	....	4,082	7,348
Pittsfield, 1 mile southeast of	5994	1	90.88	6.41	2.10	.61	.01	10.58	4.41	.09	84.30	90.20	412	742
		2	....	70.29	23.02	6.69	.11	5.26	48.36	.99	38.59	....	4,518	8,132
	5886	1	89.85	....	....	.64	.02	....	....	.10	....	89.10	514	925
		2	....	....	....	6.31	.20	....	....	.99	....	....	5,064	9,115
Smithfield	5887	1	86.06	....	....	.62	.04	....	....	.19	....	85.20	813	1,463
		2	....	....	....	4.45	.29	....	....	1.36	....	....	5,832	10,498
WASHINGTON COUNTY.														
Ayers Junction, half a mile east of	5933	1	85.22	8.86	4.72	1.20	.07	....	....	....	....	88.80	803	1,444
		2	....	59.95	31.93	8.12	.47	....	....	....	....	....	5.433	9,779
Ayers Junction, 1½ miles southwest of	5904	1	87.61	....	....	.66	.02	....	....	.11	....	86.40	657	1,183
		2	....	....	....	5.36	.16	....	....	.89	....	....	5,303	9,545
	5903	1	88.21	....	....	.66	.02	....	....	.10	....	87.10	612	1,102
		2	....	....	....	5.60	.17	....	....	.85	....	....	5,191	9,344
Cherryfield, 3½ miles northeast of	5909	1	91.27	....	....	.84	.01	....	....	.07	....	90.50	398	716
		2	....	....	....	9.62	.11	....	....	.80	....	....	4,559	8,206
East Machias, 7 miles north of	5906	1	91.96	....	....	.45	.01	....	....	.05	....	91.00	403	725
		2	....	....	....	5.42	.12	....	....	.60	....	....	4,850	8,730

Falls Point, 1 mile northwest of	5976	1	89.76	7.10	2.94	.20	.02					89.00		
		2		69.34	28.71	1.95	.20							
	5977	1	91.51	5.50	2.63	.36	.02					90.90		
		2		64.78	30.98	4.24	.24							
Forest, northwest of	5908	1	90.04			.57	.02			.12		89.10	520	936
		2				5.72	.20			1.20			5,221	9,398
Jonesboro	5911	1	90.92			.48	.02			.07		90.00	448	806
		2				5.29	.22			.77			4,934	8,881
Shoppers Point, 1½ miles northeast of	5907	1	92.87			.55	.02			.05		92.30	331	596
		2				7.71	.28			.70			4,642	8,356
Southern Inlet, east of	5905	1	89.62			.43	.02			.08		88.70	519	934
		2				4.14	.19			.77			5,000	9,000
South Lubec, three-fourths of a mile southeast of	5975	1	88.41	7.72	3.43	.44	.03	10.44	6.06	.09	82.94	87.50	574	1,033
		2		66.61	20.59	3.80	.26	5.35	52.29	.78	37.52		4,953	8,915
Vanceboro, 2 miles west of	5842	1	91.55			.68	.01			.06		89.80	400	720
		2				8.05	.12			.71			4,734	8,521
	5843	1	89.65	6.33	3.15	.87	.02			.13		87.60	536	965
		2		61.16	30.43	8.41	.19			1.26			5,179	9,322
Whitneyville, 2 miles west of	5910	1	90.28			.52	.02			.07		89.20	478	860
		2				5.35	.21			.72			4,918	8,852
YORK COUNTY.														
Kittery (Cutts Island, salt marsh)	[a] 6552	1	88.94									88.30		
Do.	[b] 6553	1	8.17	33.18	19.89	38.76	1.69					3.60	2,576	4,637
		2		36.13	21.66	42.21	1.84						2,805	5,049
Do.	[a] 6556	1	80.13									79.00		
Do.	[b] 6557	1	9.06	27.17	11.20	52.57	1.99					5.10	1,836	3,305
		2		29.88	12.31	57.81	2.19						2,019	3,634
Kittery Point (salt marsh)	[a] 6554	1	87.51									86.30		
Do.	[b] 6555	1	13.50	49.06	25.40	12.04	1.94					5.10	4,066	7,319
		2		56.72	29.36	13.92	2.24						4,701	8,462
Rosemary Junction (salt marsh)	[a] 6565	1	86.55									85.30		
Rosemary Junction (Rosemary Swamp)	[b] 6566	1	14.26	41.20	22.00	22.54	1.32					7.30	3,541	6,374
		2		48.05	25.66	26.29	1.54						4,130	7,434
Do.	[a] 6567	1	88.11									87.20		
Do.	[b] 6568	1	10.92	32.12	15.12	41.84	1.30					5.00	2,632	4,738
		2		36.06	16.97	46.97	1.46						2,955	5,319

[a] Bottle sample.

[b] Sack sample.

MASSACHUSETTS.

Analyses of moisture-free peat and muck.

[H. M. Cooper, Bureau of Mines, analyst.]

Locality No.	County.	Analysis No.	Proximate.			Ultimate.					Calorific value.	
			Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
1	Berkshire......	48	57.65	33.21	9.14	0.58	4.86	52.90	2.62	29.90	4,955	8,919
2	Essex and Suffolk..........	45	14.75	5.52	79.73	1.32	......	......	.64	......	......	......
2	.....do..........	45a	34.62	9.97	55.41	1.07	......	......	1.51	......	......	......
3	Essex..........	47	48.29	33.62	18.09	3.84	......	......	2.68	......	4,369	7,865
5	Middlesex......	26	67.45	28.51	4.04	.25	5.24	50.78	1.79	37.90	5,096	9,172
6	.....do..........	27	19.01	4.67	76.32	.16	......	......	1.00	......	......	......
9	.....do..........	29	22.46	26.01	51.53	.55	2.96	28.72	1.25	14.99	2,748	4,946
10	.....do..........	30	47.17	47.02	5.81	.36	......	......	1.90	......	5,214	9,386
11	.....do..........	31	45.93	46.99	7.08	.21	......	......	1.38	......	5,453	9,815
11	.....do..........	32	40.14	39.63	20.23	.37	......	......	1.82	......	4,611	8,299
13	.....do..........	34	32.35	32.34	35.31	1.53	3.83	37.67	2.13	19.53	......	......
13	.....do..........	34a	19.98	11.28	68.74	1.31	2.23	16.39	1.14	10.19	......	......
15	.....do..........	35	16.78	14.75	68.47	1.38	......	......	.98	......	......	......
16	.....do..........	36	21.95	18.50	59.55	.63	......	......	.98	......	......	......
19	.....do..........	37	17.81	30.39	51.80	.52	......	......	1.00	......	......	......
20	.....do..........	38	20.65	18.15	61.40	.36	......	......	1.19	......	......	......
21	.....do..........	39	14.55	8.75	76.70	.40	......	......	.82	......	......	......
22	.....do..........	40	27.33	26.50	46.17	1.10	......	......	1.41	......	......	......
23	.....do..........	41	42.13	39.88	17.99	.56	......	......	2.29	......	4,693	8,447
24	.....do..........	44	35.96	48.58	15.46	.44	......	......	1.83	......	4,871	8,767
28	Norfolk........	42	56.68	35.82	7.50	.57	4.81	55.22	1.89	30.01	5,138	9,248
28	.....do..........	42a	41.28	50.02	8.70	.50	4.55	54.75	1.95	29.55	4,984	8,973
28	.....do..........	42b	43.10	46.18	10.72	.43	4.48	53.11	2.01	29.25	4,868	8,763
29	.....do..........	43	52.90	44.36	2.74	.41	......	......	1.55	......	5,388	9,698
30	.....do..........	46	23.22	18.25	58.53	.42	2.58	24.58	1.47	12.42	......	......
30	.....do..........	46a	15.49	11.13	73.38	.25	1.57	14.48	.97	9.35	......	......
36	Worcester......	62	56.06	29.97	13.97	.39	......	......	1.72	......	5,088	9,158
37	.....do..........	63	46.20	23.31	30.49	1.32	......	......	1.61	......	......	......
38	.....do..........	28	32.19	28.13	39.68	1.29	......	......	1.32	......	......	......

Analyses of peat.[a]

[F. M. Stanton, U. S. Geological Survey, analyst.

Locality.	Laboratory No.	Condition of sample.[b]	Proximate.				Ultimate.	Air-drying loss.	Calorific value.	
			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		Calories.	British thermal units.
ESSEX COUNTY.										
Lynnfield...........	[c] 6611	1	90.18	......	......	......	......	89.50	......	......
	[d] 6612	1	21.17	46.34	23.38	9.11	0.61	15.40	4,004	7,207
		2	......	58.79	29.65	11.56	.77	......	5,079	9,142
MIDDLESEX COUNTY.										
East Lexington.....	[c] 6613	1	89.98	......	......	......	......	89.30	......	......
	[d] 6614	1	28.95	35.94	18.28	16.83	.41	23.90	3,087	5,557
		2	......	50.59	25.72	23.69	.58	......	4,345	7,821
East Lexington (machine peat)........	[d] 6622	1	15.83	45.56	25.83	12.78	.39	7.90	4,061	7,298
		2	......	54.13	30.69	15.18	.46	......	4,813	8,663
NORFOLK COUNTY.										
Norwood (Neponset Meadows bog).....	[c] 6615	1	89.37	......	......	......	......	88.40	......	......
Norwood............	[d] 6616	1	49.02	29.32	17.19	4.47	.30	44.70	2,613	4,703
		2	......	57.51	33.72	8.77	.59	......	5,126	9,227
Norwood (machine peat).............	[d] 6623	1	20.64	45.27	27.46	6.63	.43	14.10	4,104	7,387
		2	......	57.04	34.61	8.35	.54	......	5,171	9,308

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[a] Davis, C. A., The uses of peat for fuel and other purposes: Bur. Mines Bull. 16, pp. 196–197, 1911.
[b] 1, Native peat. 2, Moisture-free peat. [c] Bottle sample. [d] Sack sample.

MICHIGAN.

Analyses of moisture-free peat and muck.

[H. M. Cooper, Bureau of Mines, analyst.]

Locality No.	County.	Analysis No.	Proximate.			Ultimate.		Calorific value.	
			Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Nitrogen.	Calories.	British thermal units.
1	Dickinson	383	54.39	28.20	17.41	1.33	1.89	4,293	7,727
2	Eaton	351	36.66	49.18	14.16	.49	2.83	4,348	7,827
2	.....do	352	43.82	43.56	12.62	.50	3.00	4,481	8,066
3	Houghton	372	39.68	19.64	40.68	.36	1.44	....	....
3	.....do	373	39.28	18.69	42.03	.32	1.99	....	....
3	.....do	375	45.18	25.24	29.58	.33	1.94	....	....
4	.....do	378	55.83	31.85	12.32	.27	1.96	4,725	8,505
5	.....do	379	55.34	30.54	14.12	.61	2.53	....	....
6	Iron	380	49.47	22.98	27.55	.38	2.64	4,083	7,349
7	.....do	381	51.91	27.13	20.96	.56	1.99	4,608	8,294
8	.....do	382	41.08	17.37	41.55	.61	2.20	....	....
9	Kalamazoo	347	35.92	51.37	12.71	.46	3.58	4,557	8,203
10	.....do	348	34.51	49.50	15.99	.60	3.14	4,345	7,821
10	.....do	349	35.91	51.24	12.85	.61	2.82	4,579	8,242
10	.....do	350	37.16	52.17	10.67	.72	3.16	4,773	8,592
11	Lapeer	357	46.48	37.59	15.93	1.75	2.24	4,553	9,186
12	Luce	369	52.62	28.16	19.22	.90	1.86	4,369	7,865
13	.....do	370	55.21	23.68	21.11	.60	1.76	3,943	7,098
14	Marquette	371	52,84	31.46	15.70	.35	1.97	4,434	7,982
15	Mecosta	365	64.97	3.90	31.13	2.39	1.42	....	....
15	.....do	366	42.26	10.94	46.80	3.48	1.97	....	....
15	.....do	367	54.71	18.34	26.95	.41	1.97	3,424	6,163
15	.....do	368	57.61	16.77	25.62	2.18	1.69	3,738	6,728
16	Muskegon	364	23.84	17.84	58.32	.24	1.57	....	....
17	Oakland	356	50.46	31.00	18.54	.75	3.22	4,151	7,472
18	St. Clair	358	55.77	42.23	2.00	.27	.90	5,018	9,033
18	.....do	359	55.73	42.66	1.61	.25	.93	4,954	8,917
18	.....do	360	54.77	41.96	3.27	.22	1.43	5,039	9,071
19	Shiawassee	361	52.50	37.53	9.97	.39	3.51	4,767	8,580
19	.....do	362	52.34	37.30	10.36	.43	3.39	4,749	8,548
19	.....do	363	56.35	30.01	13.64	.57	3.25	4,627	8,328
20	Washtenaw	353	35.24	59.83	4.93	.20	2.30	5,266	9,479
20	.....do	354	41.37	54.10	4.53	.20	1.96	5,401	9,721
20	.....do	355	28.57	61.46	9.97	.23	2.55	5,201	9,362

Analyses of peat and muck.[a]

[F. M. Stanton, U. S. Geological Survey, analyst.]

Locality.	Laboratory No.	Condition of sample.[b]	Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
ALLEGAN COUNTY.														
Shelbyville, 4 miles southeast of (Gun Marsh)	[c] 6725	1	77.22									75.40		
Shelbyville, 4 miles southeast of	[d] 6724	1	49.55	21.46	9.10	19.89	0.36					45.30	1,638	2,948
		2		42.54	18.03	39.43	.71						3,247	5,845
KALAMAZOO COUNTY.														
Kalamazoo, near (Elk Marsh)	[c] 6721	1	87.76									86.80		
Do	[d] 6720	1	66.91	19.04	9.29	4.76	.09	8.97	17.23	0.81	68.14	64.30	1,680	3,024
		2		57.54	28.07	14.39	.27	4.65	52.07	2.45	26.17		5,077	9,139
Kalamazoo, near (Elk Marsh, cut peat)	[d] 6722	1	11.93	53.52	28.38	6.17	.20					4.70	4,905	8,829
		2		60.77	32.22	7.01	.23						5,570	10,026
Kalamazoo, near (machine peat)	[d] 6723	1	13.51	54.46	25.91	6.12	.26					6.50	4,722	8,500
		2		62.97	29.95	7.08	.30						5,460	9,828
LIVINGSTON COUNTY.														
Hamburg, 1 mile west of	[c] 6719	1	83.63									82.40		
Do	[c] 6718	1	53.85	30.00	13.26	2.89	.08					50.40	2,449	4,408
		2		65.00	28.74	6.26	.17						5,306	9,551
MONROE COUNTY.														
Lambertville, 12 miles north of Toledo, Ohio	[c] 6300	1	90.78									89.90		
Do	[d] 6299	1	18.65	49.13	24.31	8.01	.44					11.60	4,137	7,447
		2		60.40	29.75	9.85	.54						5,086	9,155

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[a] Davis, C. A., The uses of peat for fuel and other purposes: Bur. Mines Bull. 16, p. 197, 1911.

[b] 1, Native peat. 2, Moisture-free peat.

[c] Bottle sample.

Sack sample.

[U. S. Bureau of Mines.]

County.	Analysis No.	Locality No.	Moisture as received.	Proximate.			Ultimate.						Calorific value (British thermal units).	
				Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Nitrogen.	Hydrogen.	Carbon.	Oxygen.	Moisture free.	Moisture and ash free.
Aitkin	1	17	10.85	54.44	19.05	26.51	0.31	2.61	....	....	....	8,134	10,165
Do.	2	54	....	....	....	....	....	....	....	....	....	....	....
Do.	3	153	7.75	69.70	23.36	6.94	.20	2.01	....	....	....	9,537	10,248
Do.	4	152	7.85	69.34	21.87	8.79	.27	2.20	....	....	....	9,156	10,038
Do.	5	154	7.30	67.85	20.98	11.17	.18	2.16	....	....	....	9,435	10,621
Do.	6	155	6.60	50.80	14.03	35.17	....	2.01	....	....	....	....	....
Do.	7	156	7.95	67.30	18.09	14.61	.18	2.23	....	....	....	8,518	9,975
Do.	8	157	8.15	69.79	21.17	9.04	.16	1.69	....	....	....	8,610	9,466
Do.	9	158	7.30	68.93	23.73	7.34	.20	1.81	....	....	....	9,469	10,219
Do.	10	159	....	....	....	....	....	....	....	....	....	....	....
Do.	11	160	7.50	67.62	21.19	11.19	.18	1.92	....	....	....	8,517	9,590
Do.	12	161	....	....	....	....	....	....	....	....	....	....	....
Do.	13	162	7.95	60.95	18.79	20.26	.25	2.46	....	....	....	8,500	10,713
Do.	14	163	8.90	67.62	23.10	9.28	.23	2.06	....	....	....	8,912	9,824
Do.	15	164	10.40	68.53	21.15	10.32	.28	2.21	....	....	....	9,090	10,136
Do.	16	226	7.85	72.00	19.48	8.52	.21	2.26	....	....	....	9,593	10,487
Anoka	17	142	8.35	72.94	14.89	12.17	.27	2.87	....	....	....	8,583	9,772
Do.	18	143	9.40	62.86	20.53	16.61	.30	2.96	....	....	....	8,062	9,668
Do.	19	144	8.70	59.09	15.77	25.14	.30	2.88	....	....	....	7,456	9,960
Do.	20	145	9.00	61.43	17.75	20.82	.27	2.78	....	....	....	7,976	10,073
Becker	21	141	10.45	62.54	15.80	21.66	.95	2.27	....	....	....	9,741	12,434
Beltrami	22	15	11.18	60.63	23.33	16.04	.41	1.73	....	....	....	8,084	9,628
Do.	23	197	11.25	63.15	20.46	16.39	.33	1.51	....	....	....	7,554	9,035
Do.	24	16	11.60	53.77	18.37	27.86	.24	1.54	....	....	....	6,406	8,880
Do.	25	194	11.50	64.97	22.88	12.15	.68	2.82	....	....	....	8,429	9,595
Do.	26	195	12.10	63.14	19.85	17.01	.53	1.97	4.56	46.19	29.74	7,610	....
Do.	27	196	12.05	72.71	17.00	10.29	.25	1.31	....	....	....	7,591	8,462
Do.	28	103	8.95	71.99	12.63	15.38	1.24	2.49	....	....	....	10,906	12,888
Do.	29	104	8.25	61.12	18.23	20.65	.52	2.21	....	....	....	7,716	9,724
Do.	30	105	7.80	59.82	13.93	26.25	.84	1.98	....	....	....	7,072	9,589
Do.	31	106	6.15	43.95	10.34	45.71	....	1.60	....	....	....	....	....
Do.	32	107	7.90	59.59	18.86	21.55	1.01	2.31	....	....	....	7,703	9,819
Do.	33	108	7.60	51.01	15.44	33.55	....	1.84	....	....	....	....	....

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[a] Soper, E. K., The peat deposits of Minnesota: Minnesota Geol. Survey Bull. 16, pp. 76–81, 1919.

Analyses of peat and muck—Continued.

County.	Analysis No.	Locality No.	Moisture as received.	Proximate.				Ultimate.				Calorific value (British thermal units).	
				Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Nitrogen.	Hydrogen.	Carbon.	Oxygen.	Moisture free.	Moisture and ash free.
Beltrami	34	109	8.80	62.06	15.08	22.86	0.99	1.98	....	....	....	7,515	9,742
Do.	35	110	10.80	66.65	24.27	9.08	1.54	2.74	....	....	....	9,064	9,969
Do.	36	123	....	....	....	....	....	....	....	....	....	....	....
Do.	37	124	....	....	....	....	....	....	....	....	....	....	....
Do.	38	175	11.60	63.24	23.13	13.63	.33	1.70	....	....	....	7,752	8,975
Do.	39	176	8.75	64.88	16.33	18.79	1.58	2.88	....	....	....	8,322	10,248
Do.	40	177	11.10	59.84	20.25	19.91	.42	1.77	....	....	....	7,487	9,348
Do.	41	134	9.70	70.99	19.85	8.86	.61	2.30	....	....	....	8,765	9,617
Do.	42	137	11.15	67.75	21.95	10.30	.79	3.04	4.98	50.89	30.02	8,617	....
Do.	43	138	11.30	65.67	23.23	11.10	.83	3.13	....	....	....	8,591	9,664
Do.	44	139	10.80	74.10	17.94	7.96	.43	2.95	....	....	....	8,688	9,439
Do.	45	189	9.65	70.50	17.71	11.79	.23	2.86	....	....	....	8,550	9,693
Do.	46	190	9.80	70.84	18.46	10.70	.24	2.53	....	....	....	8,583	10,823
Blue Earth	47	99	8.60	49.87	6.64	43.49	....	2.22	....	....	....	....	....
Do.	48	100	8.90	58.95	16.74	24.31	.35	2.83	....	....	....	7,450	9,843
Do.	49	101	9.20	57.10	17.73	25.17	.33	2.86	....	....	....	7,239	9,674
Do.	50	56	6.98	43.00	8.62	48.38	.45	2.40	....	....	....	4,593	8,897
Do.	51	57	8.05	49.95	17.88	32.17	.46	2.53	....	....	....	6,525	9,620
Do.	52	59	8.23	61.75	20.51	17.74	.29	2.53	....	....	....	7,791	9,471
Do.	53	60	8.63	53.90	18.98	27.12	.26	2.35	....	....	....	6,904	9,473
Do.	54	61	8.48	49.20	16.51	34.29	.36	2.53	....	....	....	6,203	9,440
Do.	55	62	8.88	54.73	17.47	27.80	.40	2.81	....	....	....	6,736	9,330
Do.	56	63	9.53	59.88	21.57	18.55	.33	2.80	....	....	....	7,696	9,449
Do.	57	64	9.40	53.51	20.17	26.32	.39	2.72	....	....	....	6,983	9,478
Do.	58	66	9.58	56.18	19.46	24.36	.41	3.01	....	....	....	7,172	9,482
Do.	59	67	9.63	63.41	20.79	15.80	.27	2.92	....	....	....	8,023	9,528
Do.	60	70	6.83	47.12	15.34	37.54	.76	2.35	....	....	....	5,972	9,561
Do.	61	79	6.53	50.66	14.84	34.50	.45	2.75	....	....	....	6,273	9,576
Do.	62	80	7.93	59.90	19.49	20.61	.34	3.10	....	....	....	7,555	9,516
Do.	63	81	8.45	61.33	18.68	19.99	.33	3.13	....	....	....	7,566	9,457
Do.	64	82	7.65	60.18	19.03	20.79	.45	3.00	....	....	....	7,517	9,490
Carlton	65	13	11.35	65.82	23.54	10.64	.26	1.84	4.27	51.63	31.36	8,839	9,892
Do.	66	214	7.75	55.66	13.17	31.17	.31	2.76	....	....	....	6,885	10,002
Do.	67	215	7.60	68.31	23.50	8.19	.19	1.82	....	....	....	9,124	9,938
Do.	68	216	7.85	67.12	21.54	11.34	.21	2.04	....	....	....	8,932	10,075
Cass	69	125	11.20	63.91	22.75	13.43	.46	1.95	....	....	....	8,492	9,799

Do													
Do	73	166	10.70	66.01	18.59	15.40	.21	[illegible]	....	....	....	[illegible]	[illegible]
Do	74	167	9.45	73.72	18.55	7.73	.21	2.15	....	....	....	9,042	9,800
Cottonwood	75	111	7.10	41.60	3.34	55.06	....	1.92	....	....	....	....	....
Crow Wing	76	42	10.15	64.75	24.45	10.80	.28	2.84	....	....	....	8,553	9,580
Do	77	43	9.78	65.51	24.20	10.29	.43	3.03	....	....	....	8,894	9,914
Do	78	55	8.75	....	....	16.5	....	....	....	....	....	....	....
Do	79	165	7.80	61.23	17.51	21.26	.13	2.65	....	....	....	7,456	9,350
Dakota	80	253	9.00	68.02	19.40	12.58	1.34	2.40	....	....	....	8,346	9,547
Douglas	81	130	9.10	59.74	11.71	28.55	....	2.26	....	....	....	....	....
Do	82	131	10.80	64.07	18.78	17.15	.48	2.76	....	....	....	7,994	9,649
Do	83	132	10.05	57.14	17.57	25.29	.32	2.67	....	....	....	7,173	9,001
Do	84	133	11.15	66.63	16.94	16.43	.28	2.87	....	....	....	8,150	9,762
Faribault	85	102	7.40	46.14	4.08	49.78	....	2.27	....	....	....	....	....
Freeborn	86	94	7.06	41.90	9.90	48.20	.15	1.94	3.18	29.56	16.97	....	....
Do	87	94a	7.55	41.81	9.62	48.57	....	1.95	....	....	....	....	....
Do	88	94b	5.55	26.20	4.93	68.87	....	1.22	....	....	....	....	....
Do	89	95	8.45	42.85	8.16	48.99	....	2.33	....	....	....	....	....
Do	90	96	6.50	34.22	5.94	59.84	....	1.60	....	....	....	....	....
Do	91	97	9.25	52.29	13.94	33.77	....	2.75	....	....	....	....	....
Hennepin	92	246	8.55	62.00	17.66	20.34	.61	3.66	....	....	....	8,014	10,060
Do	93	247	8.60	71.01	17.67	11.32	.30	2.49	....	....	....	8,151	9,191
Do	94	248	9.06	67.89	15.29	16.82	.21	2.80	....	....	....	7,655	9,203
Do	95	249	10.10	72.02	15.97	12.01	.46	3.43	....	....	....	8,210	9,331
Do	96	250	9.50	67.73	19.95	12.32	.61	3.29	....	....	....	8,523	9,720
Do	97	252	9.10	72.66	15.79	11.55	.36	2.95	....	....	....	8,497	9,607
Hubbard	98	112	12.70	61.09	17.55	21.36	1.19	2.04	....	....	....	7,267	9,241
Do	99	113	9.30	63.89	21.45	14.66	.56	2.22	....	....	....	8,286	9,709
Do	100	113a	10.40	66.77	23.35	9.88	.37	2.05	....	....	....	8,526	9,461
Isanti	101	244	8.40	68.78	20.74	10.48	.28	2.49	....	....	....	8,960	10,008
Do	102	245	7.70	73.29	20.43	6.28	.25	2.71	....	....	....	9,538	10,178
Itasca	103	114	8.35	60.17	19.92	19.91	.23	1.96	....	....	....	7,835	9,783
Do	104	115	8.06	66.94	20.01	13.05	.24	2.12	....	....	....	8,884	10,217
Do	105	118	9.60	71.68	21.57	6.75	.29	1.75	....	....	....	8,823	9,462
Do	106	119	9.35	69.44	20.58	9.98	.23	1.65	....	....	....	8,554	9,502
Do	107	119a	9.45	69.30	19.82	10.88	.29	1.81	....	....	....	9,002	10,101
Do	108	119b	10.20	69.15	17.54	13.31	.40	2.22	....	....	....	8,700	10,038
Do	109	120	11.00	70.96	22.80	6.24	.17	1.04	....	....	....	8,366	8,923
Do	110	121	8.40	59.15	19.67	21.18	.21	2.02	....	....	....	7,854	9,964
Do	111	122	9.95	67.41	21.04	11.55	.29	2.64	....	....	....	8,732	9,872
Do	112	146	8.45	65.97	22.34	11.69	.21	2.05	....	....	....	8,875	10,050
Do	113	147	9.95	66.52	22.04	11.44	.26	2.05	....	....	....	8,580	9,688
Do	114	148	9.80	65.13	25.61	9.26	.40	1.75	....	....	....	8,588	9,464
Koochiching	115	126	10.60	58.28	18.45	23.27	.58	1.72	....	....	....	7,308	9,524
Do	116	126a	7.80	42.25	11.27	46.48	....	.93	....	....	....	....	....
Do	117	168	11.06	66.67	19.45	13.88	1.33	1.94	....	....	....	8,192	9,512
Do	118	169	10.15	69.34	21.87	8.79	.75	2.23	....	....	....	8,640	9,473
Do	119	170	11.35	68.58	20.14	11.28	.24	1.35	....	....	....	7,753	8,739
Do	120	171	10.90	64.81	23.57	11.62	.37	1.72	....	....	....	8,146	9,217
Do	121	172	8.60	67.78	20.51	11.71	.21	1.51	....	....	....	8,394	9,507
Do	122	173	9.95	68.63	22.21	9.16	.22	1.78	....	....	....	8,406	9,254

Analyses of peat and muck—Continued.

County.	Analysis No.	Locality No.	Moisture as received.	Proximate.			Ultimate.					Calorific value (British thermal units).	
				Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Nitrogen.	Hydrogen.	Carbon.	Oxygen.	Moisture free.	Moisture and ash free.
Koochiching	123	174	12.50	67.31	23.66	9.03	0.24	1.86	....	....	....	8,375	9,206
Do	124	198	10.65	67.10	23.00	9.90	.41	1.79	....	....	....	8,637	9,586
Do	125	199	10.35	67.76	24.77	7.47	.33	1.99	....	....	....	8,868	9,584
Do	126	200	9.80	74.72	18.18	7.10	.37	2.08	....	....	....	9,074	9,767
Do	127	201	9.70	74.25	20.60	5.15	.19	1.81	....	....	....	9,007	9,496
Do	128	202	9.65	74.54	21.31	4.15	.23	2.49	....	....	....	9,211	9,610
Do	129	203	10.30	72.46	20.35	7.19	.36	2.12	....	....	....	8,795	9,476
Do	130	204	9.85	69.27	22.97	7.76	.70	1.53	....	....	....	8,940	9,693
Do	131	205	10.75	68.57	21.57	9.86	.43	1.29	....	....	....	8,314	9,223
Do	132	205a	10.25	68.80	22.79	8.41	....	....	....	....	....	8,589	....
Do	133	206	9.50	73.37	20.11	6.52	.24	1.44	....	....	....	9,330	9,981
Do	134	207	9.15	70.61	23.06	6.33	.35	1.90	....	....	....	9,171	9,791
Do	135	208	9.50	81.44	13.48	5.08	.35	1.60	....	....	....	9,408	9,912
Do	136	209	9.65	82.62	11.24	6.14	.40	2.60	....	....	....	9,516	10,139
Do	137	210	10.15	71.40	22.81	5.79	.79	2.28	....	....	....	9,428	10,007
Lake	138	211	8.80	73.03	19.40	7.57	.25	1.64	....	....	....	8,815	9,537
Do	139	212	9.60	64.33	20.57	15.10	.41	1.92	....	....	....	8,144	9,592
Marshall	140	135	10.60	67.73	18.18	14.09	2.55	2.81	....	....	....	8,153	9,490
Do	141	136	9.75	70.19	18.90	10.91	1.52	2.86	....	....	....	8,666	9,727
Do	142	178	11.30	68.38	20.40	11.22	.36	3.08	....	....	....	8,452	9,520
Do	143	179	10.90	67.45	21.89	10.66	.38	2.53	....	....	....	8,506	9,521
Mille Lacs	144	225	8.55	71.90	20.61	7.49	.19	1.45	....	....	....	8,842	9,558
Morrison	145	227	8.20	66.39	20.37	13.24	.27	2.51	....	....	....	8,345	9,619
Olmsted	146	98	8.55	43.55	11.45	45.00	....	1.78	....	....	....	....	....
Ottertail	147	231	11.00	61.24	18.65	20.11	.30	1.72	....	....	....	7,288	9,422
Do	148	233	10.10	69.36	16.29	14.35	.21	3.28	....	....	....	8,135	9,498
Do	149	234	9.55	67.94	18.63	13.43	.28	2.99	....	....	....	8,199	9,471
Do	150	235	8.85	57.38	19.14	23.48	.25	2.61	....	....	....	7,277	9,510
Do	151	236	8.85	61.49	18.76	19.75	.30	2.78	....	....	....	7,865	9,801
Pine	152	217	8.10	63.77	20.07	16.16	.21	1.63	....	....	....	8,745	10,431
Do	153	218	8.75	68.38	20.61	11.01	.23	1.68	....	....	....	8,971	10,081
Do	154	219	7.70	68.85	20.26	10.89	.18	1.93	....	....	....	8,631	9,685
Do	155	220	9.25	66.61	18.73	14.66	.25	2.48	....	....	....	8,087	9,476
Do	156	221	9.45	70.62	19.05	10.33	.25	2.30	....	....	....	8,738	9,744
Do	157	222	8.60	71.39	21.55	7.06	.23	2.22	....	....	....	9,383	10,095
Do	158	223	8.00	72.77	19.95	7.28	.21	2.50	....	....	....	9,174	9,894
Do	159	224	8.70	71.74	20.43	7.83	.24	2.83	....	....	....	9,025	9,722

Polk	160	140	9.76	53.85	9.86	36.29		2.49					
Ramsey	161	83	4.85	31.11	3.73	65.16		1.50					
Do.	162	84	10.35	71.65	16.81	11.54	.21	2.88				8,210	9,281
Do.	163	85	5.75	49.50	1.53	48.97		1.81					
Do.	164	251	8.95	69.25	14.50	16.25	.44	2.97				7,708	9,203
Rice	165	254	7.50	68.65	18.81	12.54	.29	2.76				8,365	9,565
Roseau	166	127	11.45	65.95	18.86	15.19	.36	2.77				7,915	9,333
Do.	167	128	11.50	69.66	20.96	9.38	.33	2.63				8,407	9,277
Do.	168	180	10.85	71.17	20.81	8.02	.99	2.56				8,573	9,321
Do.	169	181	10.95	71.14	20.33	8.53	.73	3.01				8,837	9,561
Do.	170	182	11.05	71.22	20.80	7.98	1.29	3.04				8,886	9,657
Do.	171	183	11.60	71.21	22.23	6.56	.44	2.52				8,855	9,477
Do.	172	184	10.15	70.28	21.04	8.68	.62	2.68				8,538	9,350
Do.	173	185	7.65	43.69	11.81	44.50	.31	1.83				5,010	9,027
Do.	174	186	11.25	69.01	19.33	11.66	.79	2.45				8,247	9,336
Do.	175	187	11.70	65.46	22.25	12.29	.58	2.70				7,985	9,104
Do.	176	188	10.00	69.17	22.83	8.00	.37	2.26				8,544	9,287
Do.	177	191	7.85	37.98	6.89	55.13	.15	1.03				4,042	9,008
Do.	178	192	10.85	73.02	16.94	10.04	.25	2.16				8,328	9,257
Do.	179	193	9.90	69.26	18.20	12.54	.64	2.16	5.20	48.32	31.14	8,232	
St. Louis	180	1	10.18	59.14	20.88	19.98	.33	1.83				8,134	10,165
Do.	181	2	11.00	51.63	18.31	30.06	1.09	2.01				6,917	9,890
Do.	182	213	7.60	66.65	21.41	11.94	.20	1.64				8,986	10,204
Do.	183	5	11.85	50.31	15.79	33.90	.40	1.40				5,995	9,070
Do.	184	7	11.18	58.51	21.64	19.85	.28	1.88				7,743	9,660
Do.	185	6	10.55	62.72	23.16	14.12	.30	1.79				8,590	10,003
Do.	186	8	10.85	64.87	24.19	10.94	.27	1.39	4.90	49.32	33.18	8,363	9,391
Do.	187	9	11.60	62.25	22.65	15.10	.34	2.51				8,467	9,973
Do.	188	10	14.33	59.82	26.66	13.52	.29	1.63				7,862	9,091
Do.	189	11	12.65	60.82	26.01	13.17	.29	2.16				8,490	9,778
Do.	190	12	14.05	60.71	20.85	18.44	.52	1.65				7,466	9,154
Do.	191	18	14.58	65.73	23.97	10.30	.28	2.62				8,950	9,978
Do.	192	19	26.43	62.62	20.69	16.69	.24	2.26				8,289	9,949
Do.	193	20	14.53	64.96	25.04	10.00	.25	2.49	4.83	53.88	28.55	8,896	9,884
Do.	194	21	13.45	67.51	24.40	8.09	.24	2.58	5.23	53.24	30.62	9,153	9,959
Do.	195	21a	40.35	69.66	20.37	9.97	.34	2.35				8,899	9,884
Do.	196	22	12.48	66.64	24.79	8.57	.26	2.38	5.29	52.91	30.59	9,149	10,006
Do.	197	23	13.38	65.65	24.16	10.19	.18	1.93				8,698	9,685
Do.	198	244	24.00	66.22	23.45	10.33	.14	1.76				8,930	9,959
Do.	199	25	20.10	61.95	24.62	13.43	.29	1.68				8,150	9,415
Do.	200	26	16.73	61.63	22.94	15.43	.31	1.95				8,098	9,575
Do.	201	27	12.80	61.50	22.41	16.09	.31	2.68				8,403	10,014
Do.	202	28	14.20	64.25	23.77	11.98	.31	2.67				8,902	10,114
Do.	203	29	36.60	62.98	18.91	18.11	.25	2.03				7,953	9,711
Do.	204	30	9.83	63.62	24.07	12.31	.30	2.64				8,762	9,992
Do.	205	31	11.03	66.54	24.88	8.58	.26	2.69	5.63	52.41	30.73	9,056	9,906
Do.	206	32	10.78	74.17	22.60	13.23	.21	2.68				8,637	9,954
Do.	207	33	13.55	62.06	22.87	15.07	.22	2.73				8,351	9,832
Do.	208	34	16.83	63.91	24.01	12.08	.37	2.56				8,649	9,837
Do.	209	35	16.53	60.98	24.28	14.74	.29	2.34				8,409	9,863
Do.	210	36	40.35	65.72	21.04	13.24	.28	2.43				8,620	9,936
Do.	211	37	12.60	68.97	23.84	7.18	.21	2.17	5.42	52.93	32.08	9,265	9,983
Do.	212	38	10.20	63.81	27.92	8.27	.27	1.15	4.74	52.43	33.14	8,849	9,646

Analyses of peat and muck—Continued.

County.	Analysis No.	Locality No.	Moisture as received.	Proximate.			Ultimate.					Calorific value (British thermal units).	
				Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Nitrogen.	Hydrogen.	Carbon.	Oxygen.	Moisture free.	Moisture and ash free.
St. Louis	213	39	12.10	66.15	25.20	8.65	0.23	1.75	5.12	53.44	58.50	9,146	10,012
Do	214	40	11.63	60.15	23.84	16.01	.65	2.32				8,240	9,811
Do	215	41	9.25	58.90	17.13	23.97	.37	2.62				7,949	10,456
Do	216	41a	9.83	67.26	22.67	10.07	.40	1.80	5.25	52.17	30.31	9,057	10,072
Do	217	44	8.55	69.91	24.32	5.77	.23	1.49				9,196	9,759
Do	218	45	8.88	69.94	21.88	8.18	.30	2.80				9,059	9,867
Do	219	46	8.50	63.42	23.38	13.20	.25	2.17				8,693	10,015
Do	220	47	8.45	66.77	21.92	11.31	.26	2.47				9,061	10,216
Do	221	48	8.75	69.02	22.76	8.22	.24	2.70				8,985	9,790
Do	222	49	9.28	64.32	25.65	10.03	.25	1.85				9,010	10,015
Do	223	50	8.80	65.90	26.50	7.60	.27	2.32				9,173	9,928
Do	224	51	6.45	50.08	19.40	30.52	.16	1.51				7,458	10,734
Do	225	52	9.88	62.36	24.49	13.15	.36	2.42				8,753	10,078
Do	226	53	10.10	63.07	24.36	12.57	.32	2.53				8,778	10,040
Do	227	116	9.40	70.64	20.14	9.22	.19	1.40				8,285	9,126
Do	228	117	10.15	69.65	21.45	8.90	.30	2.09				8,648	9,493
Do	229	117a	10.55	66.74	20.96	12.30	.38	1.93				8,381	9,556
Sherburne	230	243	5.80	50.96	10.24	38.80	.23	2.28				6,162	10,069
Do	231	14	9.93	51.43	13.82	34.75	1.07	2.33				6,213	9,522
Stearns	232	129	8.95	57.94	16.30	25.76	.45	2.69				7,183	9,675
Do	233	242	7.50	54.81	10.92	34.27	.37	3.11				6,381	9,707
Steele	234	86	7.75	46.02	11.22	42.76		2.23					
Do	235	87	7.55	49.92	9.57	40.51		2.90					
Do	236	91	8.40	49.13	11.13	39.74		2.24					
Do	237	92	8.85	53.52	11.81	34.67		2.40					
Do	238	93	7.05	52.12	4.20	43.68	.33	2.25	3.29	30.01	20.44		
Todd	239	237	8.90	61.92	18.66	19.43	.30	2.78				8,024	9,959
Do	240	239	8.55	58.12	19.41	22.47	.24	2.88				7,403	9,548
Do	241	240	9.05	57.12	13.25	29.63	.74	2.84				6,412	9,112
Do	242	241	9.65	64.42	21.47	14.11	.29	2.91				8,165	9,506
Wadena	243	230	8.80	59.27	13.10	27.63	.21	2.72				6,707	9,268
Waseca	244	88	12.00	61.02	20.23	18.75	.47	2.93				7,887	9,707
Do	245	89	8.75	57.26	14.90	27.84	.28	3.08	4.28	38.67	25.85	6,139	6,728
Do	246	90	8.45	48.26	14.33	37.41		1.73					

NEW HAMPSHIRE.

Analyses of moisture-free peat and muck.

[H. M. Cooper, Bureau of Mines, analyst.]

Locality No.	County.	Sample and analysis No.	Proximate.			Ultimate.					Calorific value.	
			Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
1	Cheshire	7	35.18	49.88	14.94	0.29	......	......	1.60	......	4,654	8,377
2	.....do	8	51.02	45.00	3.98	.16	......	......	1.76	......	5,333	9,599
5	Hillsborough	3	44.36	50.28	5.36	.20	5.56	56.40	2.03	30.45	5,444	9,800
6	.....do	4	28.41	34.17	37.42	.34	......	......	1.44	......	......	......
7	.....do	5	35.00	33.25	31.75	.32	......	......	1.97	......	......	......
8	.....do	6	43.58	35.54	20.88	.31	......	......	1.82	......	4,109	7,396
10	Rockingham	1	17.59	9.38	73.03	1.54	......	......	1.10	......	......	......
16	.....do	2	68.50	26.40	5.10	.37	......	......	1.69	......	5,648	10,166

Analyses of peat and muck.[a]

[F. M. Stanton, U. S. Geological Survey, analyst.]

Locality.	Laboratory No.	Condition of sample.[b]	Proximate.				Ultimate.	Air-drying loss.	Calorific value.	
			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		Calories.	British thermal units.
ROCKINGHAM COUNTY.										
Fremont	[c] 6575	1	89.60	......	......	......	......	89.00	......	......
Do	[d] 6576	1	14.49	53.03	25.24	7.24	0.63	8.70	4,712	8,382
		2	......	62.02	29.51	8.47	.74	......	5,511	9,920
Greenland (Great Bay salt-marsh peat)	6569	1	10.86	27.68	12.70	48.81	1.55	5.60	2,004	3,607
		2	......	31.00	14.24	54.76	1.74	......	2,248	4,046
Greenland (Great Swamp)	[c] 6570	1	77.96	......	......	......	......	76.80	......	......
Do	[d] 6571	1	12.97	42.74	21.82	22.47	.94	6.80	3,721	6,698
		2	......	49.11	25.07	25.82	1.08	......	4,275	7,695
Rye (salt-marsh peat)	[c] 6561	1	82.83	......	......	......	......	81.40	......	......
Do	[d] 6562	1	12.61	46.72	24.86	15.81	1.52	6.10	4,093	7,367
		2	......	53.46	28.45	18.09	1.74	......	4,684	8,431
STRAFFORD COUNTY.										
Dover	[c] 6573	1	85.49	......	......	......	......	84.50	......	......
Do	[d] 6574	1	15.8	52.67	27.02	4.51	.46	9.30	4,552	8,194
		2	......	62.55	32.09	5.36	.55	......	5,406	9,731
Farmington, 4 miles north of (Ely River bog)	[c] 6577	1	89.76	......	......	......	......	89.10	......	......
Farmington, 4 miles north of	[d] 6578	1	13.68	42.90	20.28	23.14	.59	8.10	3,647	6,565
		2	......	49.70	23.49	26.81	.68	......	4,225	7,605
New Durham (Merrymeeting Bog)	[c] 6579	1	88.15	......	......	......	......	87.30	......	......
Do	[d] 6580	1	12.82	48.30	22.25	16.63	.82	7.20	4,097	7,375
		2	......	55.40	25.52	19.08	.94	......	4,700	8,460
Rochester	[d] 6572	1	11.64	58.97	25.33	4.06	.22	7.20	5,046	9,083
		2	......	66.74	28.67	4.59	.25	......	5,711	10,280

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[a] Davis, C. A., The uses of peat for fuel and other purposes: Bur. Mines Bull. 16, pp. 197-198, 1911.
[b] 1, Native peat. 2, Moisture-free peat.
[c] Bottle sample.
[d] Sack sample.

NEW JERSEY.

Analyses of moisture-free peat.

[H. M. Cooper, Bureau of Mines, analyst.]

Locality.	Sample and analysis No.	Proximate.			Ultimate.		Calorific value.	
		Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Nitrogen.	Calories.	British thermal units.
SUSSEX COUNTY.								
Netcong	1	57.76	33.34	8.90	0.44	1.87	5,068	9,122
Do	2	55.51	37.44	7.05	.49	2.38	5,038	9,068

Analyses of high-grade air-dried peat.[a]

Locality (nearest town).	Locality number (Pl. XII).	Sample and analysis No.	Ash.	Nitrogen.	Calories.	Coke.
Allendale	5	3	5.04	2.17	5,876	29.20
Sussex	20	44	7.27	2.10	4,589	36.11
Stockholm	26	58	5.75	2.10	5,284	35.31
Dunker Pond	26	59	6.24	2.11	5,265	34.30
Mount Hope	29	68	5.14	1.27	5,645	43.85
Do	29	70	9.47	1.87	5,159	38.76
Ironia	32	72	9.34	1.17	5,488	37.64
Bog and Vly	47	102	7.28	2.16	5,378	37.08
Southtown	58	112	6.54	1.62	5,098	34.30
Westwood	4	115	7.30	2.11	5,203	33.51
Kerr's Corner	58	117	8.01	2.35	5,120	32.63
Do	58	118	7.72	1.59	4,982	36.70
Danville	56	119	8.62	2.45	4,953	33.14
Franklin Lake	63	130	8.34	2.03	5,521	36.28
East Newton	12	15	10.34	2.24	5,187	33.09
Lafayette	15	22	10.45	2.83	5,004	34.91
Sussex	19	34	11.38	2.34	4,946	37.95
Do	25	46	14.59	2.13	4,878	39.77
Van Sickle	22	47	13.04	2.25	4,986	40.01
Rockport	22	48	11.36	2.02	4,908	37.53
Vernon	23	54	14.40	2.73	4,707	36.92
Ironia	32	73	14.26	1.30	5,193	41.78
Rockaway	33	75	10.54	2.11	5,057	32.25
Black Meadows	37	83	12.43	2.05	4,791	38.81
Great Meadows	37	84	10.84	1.88	4,885	37.45
Great Swamp	38	89	13.86	2.07	4,947	40.09
Troy Meadows	41	92	10.60	1.46	5,272	37.80
Do	41	93	13.44	1.98	4,901	38.96
Pequannock	45	98	12.69	1.61	4,789	39.15
Danville	56	110	11.04	1.98	5,234	36.90
Do	56	111	13.31	1.96	4,562	40.26
Southtown	58	116	13.42	2.52	4,795	36.83
Woodbridge	....	....	10.40	2.62	4,926	34.40
Buttsville	61	125	10.41	2.65	4,863	34.51
Pompton Plains	63	128	13.64	2.11	4,767	41.55

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[a] Parmelee, C. W., and McCourt, W. E., A report on the peat deposits of northern New Jersey: New Jersey Geol. Survey Ann. Rept. for 1905, p. 261, 1905.

Analyses of low-grade air-dried peat and muck.[a]

Locality (nearest town).	Locality No. (Pl. XII).	Sample and analysis No.	Ash.	Calories.	Coke.
Allendale	5	2	18.89	4,388	41.57
Hackensack	9	9	20.74	4,312	46.75
Springdale	10	11	24.43	4,041	....
East Newton	12	16	23.78	4,212	43.73
Lafayette	15	19	23.29	4,092	44.85
Sparta Junction	15	23	20.88	4,026	40.20
Sussex	19	31	20.11	4,165	41.90
Beemersville	21	35	17.23	4,814	41.40
Do.	21	36	20.82	4,199	39.38
Do.	21	40	23.03	4,212	44.35
Wykertown	21	42	22.81	4,377	44.18
Harmonyvale	25	57	23.25	4,027	42.60
Wyckoff	27	60	24.70	4,049	45.90
Berkshire Valley	27	61	18.21	4,387	46.26
Do.	28	63	24.95	4,276	47.10
Do.	28	64	23.24	4,456	46.01
Do.	28	65	20.10	4,800	41.95
Do.	28	66	24.38	4,300	45.20
Mount Hope	29	67	16.44	5,117	42.65
Kenvil	31	71	19.27	4,285	42.94
Rockaway	33	76	16.46	5,049	41.10
Chester	32	94	17.61	4,575	42.29
Dismal Swamp	50	105	20.43	4,335	42.35
Newark Meadows	53	108	20.06	4,347	43.55
Johnsonburg	57	120	15.82	4,317	36.35
Mount Herman	60	124	16.71	4,568	36.46
Pigeon Swamp	62	126	20.40	4,539	37.25

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[a] Parmelee, C. W., and McCourt, W. E., A report on the peat deposits of northern New Jersey: New Jersey Geol. Survey Ann. Rept. for 1905, p. 262, 1905.

NEW YORK.

Analyses of moisture-free peat and muck.

[H. M. Cooper, Bureau of Mines, analyst.]

Locality No.	County.	Sample and analysis No.	Proximate.			Ultimate.					Calorific value.	
			Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
2	Clinton	18	43.45	32.78	23.77	0.31	....	....	2.53	....	3,701	6,662
3	.....do	19	33.68	26.65	39.67	.28	....	....	1.86	....	....	....
5	Dutchess	74	59.22	33.39	7.39	.44	4.78	45.41	1.72	40.26	5,106	9,190
5	.....do	74a	60.74	35.50	3.76	.22	5.16	54.97	1.57	34.32	5,324	9,583
9	Essex	20	36.04	53.55	10.41	.74	....	....	3.70	....	4,748	8,547
9	.....do	20a	45.06	48.07	6.87	.36	....	....	3.00	....	4,828	8,690
10	Essex and Franklin	21	41.46	52.00	6.54	.36	....	....	2.12	....	5,069	9,125
10	Franklin	22	45.55	43.30	11.15	.36	....	....	1.70	....	4,862	8,752
13	.....do	23	57.67	37.39	4.94	.22	....	....	2.34	....	5,534	9,962
15	.....do	24	43.08	47.82	9.10	.41	....	....	2.37	....	5,094	9,169
15	.....do	25	46.55	41.89	11.56	.30	....	....	2.06	....	4,930	8,874
16	Genesee and Orleans	69	63.72	21.91	14.37	1.43	....	....	3.01	....	4,402	7,923
16	.....do	70	59.76	26.43	13.81	1.45	3.56	46.94	2.87	31.37	4,489	8,080
24	Onondaga	64	61.59	31.07	7.34	.39	4.74	54.07	2.02	31.44	5,142	9,256
24	.....do	65	62.01	30.14	7.85	.44	....	....	2.16	....	4,976	8,957
25	.....do	66	60.10	29.92	9.98	1.45	....	....	2.30	....	4,743	8,537
26	Orange	71	55.25	24.19	20.56	.97	....	....	2.74	....	4,431	7,975
27	.....do	72	59.87	26.45	13.68	1.48	4.74	49.51	2.89	27.70	4,651	8,372
27	.....do	73	54.59	22.21	23.20	1.69	4.27	35.85	2.46	32.53	4,147	7,465
30	Seneca and Wayne	67	64.50	2.68	32.82	1.38	....	....	....	....	....	....
31	.....do	68	59.23	8.20	32.57	2.73	....	....	2.59	....	....	....

Analyses of peat and muck.[a]

Locality.	Laboratory No.	Condition of sample.[b]	Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
ESSEX COUNTY.														
Bloomingdale	c6430	1	89.06	....	....	....	....	....	....	....	....	88.30	....	....
	d6429	1	12.01	57.14	28.07	2.78	0.23	....	....	....	....	8.20	4,931	8,876
		2	....	64.94	31.90	3.16	.26	....	....	....	....	....	5,604	10,087
FRANKLIN COUNTY.														
Mountain View	c6428	1	88.40	....	....	....	....	....	....	....	....	87.60	....	....
	d6427	1	11.01	59.71	25.80	3.48	.13	6.50	50.88	1.32	37.69	7.30	5,096	9,172
		2	....	67.10	28.99	3.91	.15	5.93	57.17	1.48	31.36	....	5,726	10,307
Saranac Lake	d6431	1	11.74	43.84	13.23	31.19	.84	....	....	....	....	8.60	3,244	5,839
		2	....	49.67	14.99	35.34	.95	....	....	....	....	....	3,675	6,615
LIVINGSTON COUNTY.														
South Lima	c6663	1	69.20	....	....	....	....	....	....	....	....	66.30	....	....
	d6664	1	56.70	26.14	11.17	5.99	.64	8.33	21.03	1.10	62.91	53.40	1,992	3,586
		2	....	60.37	25.80	13.83	1.48	4.69	48.57	2.54	28.89	....	4,600	8,280
MADISON COUNTY.														
Canastota	d6638	1	24.70	45.51	20.63	9.16	.42	6.22	36.13	1.87	46.20	17.80	3,274	5,893
		2	....	60.44	27.40	12.16	.56	4.62	47.98	2.48	32.20	....	4,348	7,826
ONONDAGA COUNTY.														
Cicero	c6399	1	89.70	....	....	....	....	....	....	....	....	89.20	....	....
	d6398	1	14.57	54.80	23.21	7.42	.25	....	....	....	....	9.90	4,209	7,576
		2	....	64.14	27.17	8.69	.29	....	....	....	....	....	4,927	8,869
Elbridge, 2 miles east of Big Swamp Bog	d7080	1	9.32	37.00	18.83	34.85	.97	....	....	....	....	4.40	3,048	5,486
		2	....	40.80	20.77	38.43	1.07	....	....	....	....	....	3,361	6,050
Half Way	d7081	1	9.98	36.46	17.17	36.39	1.60	....	....	....	....	5.00	2,976	5,357
		2	....	40.50	19.07	40.43	1.78	....	....	....	....	....	3,306	5,951
Memphis	d7078	1	7.39	24.31	9.69	58.61	1.26	....	....	....	....	3.10	1,809	3,256
		2	....	26.25	10.46	63.29	1.36	....	....	....	....	....	1,953	3,515
ORLEANS COUNTY.														
Oak Orchard	c6397	1	60.87	....	....	....	....	....	....	....	....	58.90	....	....
	d6396	1	25.40	42.48	9.38	22.74	.45	5.66	25.26	1.96	43.93	20.20	2,288	4,118
		2	....	56.94	12.58	30.48	.60	3.81	33.86	2.63	28.62	....	3,067	5,521
	c6405	1	86.88	....	....	....	....	....	....	....	....	86.20	....	....
	d6404	1	16.52	49.75	21.75	11.98	1.49	....	....	....	....	10.20	3,784	6,811
		2	....	59.60	26.05	14.35	1.78	....	....	....	....	....	4,533	8,159
	c6403	1	87.20	....	....	....	....	....	....	....	....	86.50	....	....
	d6402	1	15.59	49.37	20.44	14.60	1.64	....	....	....	....	10.10	3,834	6,901
		2	....	58.49	24.21	17.30	1.94	....	....	....	....	....	4,542	8,176

OSWEGO COUNTY.														
Fulton, 7 miles east of	[c]6636	1	93.96	......	......	......	......	......	......	......	......	93.50	......	......
	[d]6637	1	54.66	29.15	12.44	3.75	.17	......	......	......	......	51.60	2,280	4,104
		2	......	64.29	27.44	8.27	.37	......	......	......	......	......	5,029	9,052
Hastings, 4 miles west of Central Square	[d]7079	1	7.03	31.60	17.46	43.91	.74	......	......	......	......	2.80	2,557	4,603
		2	......	33.99	18.78	47.23	.80	......	......	......	......	......	2,750	4,950
Palermo	[c]6634	1	90.44	......	......	......	......	......	......	......	......	89.40	......	......
	[d]6635	1	74.78	15.29	7.47	2.46	.16	......	......	......	......	72.40	1,237	2,227
		2	......	60.63	29.62	9.75	.63	......	......	......	......	......	4,905	8,829
West Monroe	[c]6401	1	92.27	......	......	......	......	......	......	......	......	91.90	......	......
	[d]6400	1	18.45	44.55	24.55	12.45	.75	5.95	41.63	1.71	37.51	12.10	3,994	7,189
		2	......	54.63	30.10	15.27	.92	4.78	51.05	2.10	25.88	......	4,897	8,815
ST. LAWRENCE COUNTY.														
Ogdensburg, near Black Lake Bog (machine peat)	[c]6393	1	11.54	......	......	......	......	......	......	......	......	6.20	......	......
	[d]6392	1	12.00	49.43	21.59	16.98	.91	......	......	......	......	5.00	3,897	7,015
		2	......	56.17	24.53	19.30	1.03	......	......	......	......	......	4,428	7,971
Ogdensburg, near Black Lake Bog (peat from barge)	[d]6436	1	16.81	46.39	21.67	15.13	.90	......	......	......	......	8.90	3,807	6,853
		2	......	55.77	26.04	18.19	1.08	......	......	......	......	......	4,576	8,237
Ogdensburg, near Black Lake Bog (machine peat)	[d]6394	1	16.67	45.81	21.47	16.05	.82	......	......	......	......	8.10	3,727	6,709
		2	......	54.97	25.77	19.26	.98	......	......	......	......	......	4,472	8,050
Ogdensburg, near Black Lake Bog (briquetted peat)	[d]6395	1	16.37	47.44	20.40	15.79	1.06	......	......	......	......	9.10	3,811	6,860
		2	......	56.73	24.39	18.88	1.27	......	......	......	......	......	4,557	8,203
STEUBEN COUNTY.														
Arkport	[c]7083	1	87.45	......	......	......	......	......	......	......	......	86.60	......	......
	[d]7082	1	13.18	43.33	20.50	22.99	1.38	......	......	......	......	7.00	3,493	6,287
		2	......	49.91	23.61	26.48	1.59	......	......	......	......	......	4,023	7,241

[a] Davis, C. A., The uses of peat for fuel and other purposes: Bur. Mines Bull. 16 .pp. 198-199, 1911.

[b] 1, Native peat; 2, Moisture-free peat.

[c] Bottle sample.

[d] Sack sample.

OHIO.

Analyses of moisture-free peat and muck.[a]

[Bureau of Mines.]

County.	Deposit No.	Laboratory No.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Nitrogen.	Sulphur.	Iron.	Calorific value (British thermal units).
Ashland	1	73-11122	7.14	67.42	24.91	7.67	2.39	0.28	0.39	9,070
Ashtabula	2	44-10773	9.08	63.24	26.18	10.58	2.45	.46	....	8,966
Champaign	3	60-11008	10.73	57.01	26.43	16.56	2.56	1.21	....	7,567
Columbiana	4	24-	10.96	50.29	23.75	25.90	2.42	.80	....	7,520
Crawford	5	64-11014	9.24	54.87	25.62	19.51	2.70	.90	....	7,448
Do	6	89-12477	13.53	67.52	27.05	10.43	3.23	.47	....	8,683
Cuyahoga	7	49-10778	9.01	51.05	23.51	25.44	2.13	.77	....	7,504
Darke	8	88-12476	12.72	43.44	11.48	45.08	2.30	.35	....	4,637
Do	9	87-12475	16.24	54.75	19.51	25.74	3.05	.64	....	6,797
Defiance	10	82-11348	8.58	62.44	25.44	12.32	2.58	.52	....	8,420
Do	11	83-11349	8.97	60.53	27.96	11.51	2.90	.36	....	8,566
Fairfield	12	66-11115	7.58	57.72	21.02	21.26	3.25	4.21	....	7,603
Geauga	13	49-10778	9.01	51.05	23.51	25.44	2.13	.77	....	7,504
Do	14	51-10798	10.11	60.09	27.96	11.95	2.24	.29	....	8,741
Greene	15	85-12473	15.56	58.72	24.20	17.08	3.60	1.92	....	8,248
Hancock	16	38-10687	11.02	56.72	23.56	19.72	3.48	1.67	....	7,749
Hardin	17	61-11010	10.85	58.86	26.90	14.24	3.37	1.22	....	7,916
Do	18	62-11012	10.81	60.67	27.51	11.82	3.41	.98	....	7,996
Holmes	19	72-11121	6.96	69.51	25.04	5.81	2.38	.23	.23	9,571
Huron	20	42-10733	8.77	59.73	29.39	10.88	2.84	.95	....	8,914
Do	21	64-11014	13.53	67.52	27.05	10.43	3.23	.47	....	8,683
Licking	22	43-10772	9.90	61.63	27.11	11.26	2.21	.64	....	8,122
Do	23	40-10709	7.87	74.79	21.35	3.86	2.52	.28	....	8,338
Do	24	41-10710	9.23	67.09	24.46	8.45	1.01	.43	....	8,626
Mahoning	25	50-10797	10.01	61.97	29.05	8.98	2.66	.31	....	8,737
Medina	26	70-11119	7.53	55.60	26.69	17.71	2.58	.69	1.34	8,168
Do	27	71-11120	7.67	56.93	20.93	22.14	2.55	4.57	2.16	7,132
Mercer	28	81-11347	8.72	64.51	28.12	7.37	2.77	.51	....	8,915
Do	29	80-11321	9.28	55.79	25.77	18.44	3.19	1.38	1.02	7,781
Do	30	79-11320	10.23	55.72	24.49	19.79	2.97	1.10	.84	7,762
Montgomery	31	84-12472	7.02	26.83	6.20	66.97	.93	.55	....	2,914
Portage	32	55-10814	8.65	68.01	25.91	6.08	3.01	.26	....	9,443
Do	33	52-10806	11.25	57.64	31.19	11.17	2.33	.74	....	8,564
Do	34	53-10805	8.41	57.58	27.64	14.78	1.62	.25	....	8,996
Do	35	56-10815	9.36	66.73	29.62	3.65	1.66	.21	....	9,736
Do	36	47-10777	10.40	56.33	26.16	17.51	2.46	.86	....	8,190
Do	37	46-11007	9.12	40.37	18.16	41.47	1.72	.43	....	5,121
Do	38	54-10813	8.98	56.52	25.65	17.63	2.21	.40	....	8,402
Seneca	39	38-10687	11.02	56.72	23.56	19.72	3.48	1.67	....	7,749
Shelby	40	86-12474	16.28	57.20	24.46	18.34	2.66	.57	....	7,675
Stark	41	74-11147	10.43	57.32	33.39	9.29	2.94	.38	.18	7,794
Do	42	75-11148	8.82	53.75	33.64	12.61	2.79	.37	.19	8,498
Do	43	76-11149	8.01	62.03	31.84	6.13	3.39	.33	.18	8,842
Summit	44	59-10832	11.35	56.86	31.87	11.28	2.72	.89	....	8,861
Do	45	58-10830	10.54	60.66	28.92	10.42	2.88	.75	....	8,703
Do	46	57-10829	8.91	59.32	26.38	14.30	2.34	.98	....	8,372
Trumbull	47	45-10774	8.38	59.62	22.64	17.74	2.73	.38	....	8,147
Wayne	48	67-11116	7.00	61.83	27.20	10.96	2.97	.81	....	8,608
Do	49	68-11117	7.44	63.29	32.14	4.57	2.22	.27	.23	9,569
Do	50	69-11118	7.60	57.73	26.08	16.19	2.59	.42	1.38	8,280
Do	51	77-11318	7.27	66.44	29.63	3.93	2.30	.24	....	9,148
Do	52	78-11319	6.99	54.46	25.02	20.52	2.41	.89	....	7,875
Williams	53	33-13180	10.12	63.61	23.34	13.05	2.63	.29	....	8,345
Do	54	34-13181	10.41	59.94	28.01	12.05	2.93	.34	....	8,532
Do	55	63-11046	9.09	62.21	30.20	7.59	2.03	.21	....	9,389
Do	56	90-13182	8.38	70.02	20.26	9.72	3.36	.24	....	8,914
Do	57	65-11047	12.01	64.43	16.56	19.01	2.43	.54	....	8,905
Wyandot	58	35-10684	10.63	57.25	28.14	14.61	2.98	1.13	....	8,378
Do	59	36-10685	10.35	57.04	29.41	13.55	2.84	1.43	....	8,482
Do	60	37-10686	9.85	57.17	21.90	20.93	2.92	1.95	....	7,682
Do	61	39-10688	8.84	51.85	25.12	23.03	2.16	2.18	....	7,666

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[a] Dachnowski, Alfred, Peat deposits of Ohio, their origin, formation, and uses: Ohio Geol. Survey Bull. 16, 4th ser., pp. 366-367, 1912.

PENNSYLVANIA.

Analyses of moisture-free peat.

[H. M. Cooper, Bureau of Mines, analyst.]

County.	Locality No.	Analysis No.	Proximate.			Ultimate.		Calorific value.	
			Volatile matter.	Fixed carbon.	Ash.	Nitrogen.	Sulphur.	Calories.	British thermal units.
Columbia	1	1	45.84	28.99	25.17	2.03	0.61	4,257	7,662
Do	2	2	52.92	19.29	27.79	2.07	1.49	4,041	7,274

RHODE ISLAND.

Analyses of moisture-free peat and muck.

[H. M. Cooper, Bureau of Mines, analyst.]

Locality No.	County.	Analysis and sample No.	Proximate.			Ultimate.			Calorific value.	
			Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Nitrogen.	Oxygen.	Calories.	British thermal units.
1	Bristol	52	42.43	19.82	37.75	1.01	1.51	....	....	....
2	Providence	49	45.19	31.11	23.70	.30	1.56	....	4,298	7,737
4	.....do	51	40.65	21.85	37.50	.54	1.59	....	....	....
5	.....do	50	44.49	34.64	20.87	.44	1.77	....	4,612	8,301

VERMONT.

Analyses of moisture-free peat and muck.

[H. M. Cooper, Bureau of Mines, analyst.]

Locality No.	County.	Sample and analysis No.	Proximate.			Ultimate.					Calorific value.	
			Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
1	Addison	9	40.06	42.08	17.86	0.75	....	....	2.37	....	4,318	7,773
1	.....do	9a	48.70	10.07	41.23	.56	....	....	1.68	....	....	....
2	.....do	10	37.37	14.02	48.61	1.19	....	....	1.81	....	....	....
3	.....do	11	56.39	35.53	8.28	.56	5.40	49.98	2.65	33.13	4,771	8,588
3	.....do	11a	38.75	21.05	40.20	.65	4.13	32.10	2.24	20.68	....	....
4	.....do	12	48.71	40.25	11.04	.57	....	....	2.73	....	4,689	8,440
8	Chittenden	13	42.01	45.02	12.97	.39	....	....	2.18	....	4,704	8,467
9	.....do	14	25.26	37.36	37.38	.43	....	....	2.78	....	....	....
14	Grand Isle	15	34.47	21.38	44.15	.22	....	....	1.68	....	....	....
16	.....do	16	48.70	45.19	6.11	.28	4.88	53.21	1.90	33.62	4,944	8,899
19	.....do	17	36.01	52.53	11.46	1.04	....	....	2.44	....	4,781	8,606

Analyses showing average composition of moisture-free peat.[a]

County.	No. of samples represented.	Proximate.		Ultimate.				Calorific value.	
		Volatile matter.	Ash.	Hydrogen.	Carbon.	Nitrogen.	Oxygen and sulphur.	Calories.	British thermal units.
Addison	14	88.22	11.78	4.30	47.91	2.62	33.39	4,302	7,740
Bennington	13	86.50	13.50	4.36	46.78	2.29	33.07	4,248	7,630
Chittenden	24	92.96	7.04	4.87	52.04	1.85	34.20	4,832	8,690
Franklin	15	91.97	8.03	4.52	50.23	1.89	35.33	4,530	8,180
Grand Isle	36	88.22	11.78	4.65	45.87	2.70	35.00	4,206	7,580
Lamoille	8	90.03	9.97	4.09	48.83	2.13	34.98	4,272	7,690
Orange	5	84.84	15.16	4.41	45.56	2.78	32.09	4,183	7,520
Orleans	5	90.48	9.52	4.42	49.82	2.33	33.91	4,493	8,090
Washington	3	92.17	7.83	5.24	49.84	2.70	34.69	4,743	8,520
Windham	6	92.26	6.74	4.92	50.32	1.88	36.14	4,651	8,360
Windsor	9	94.75	5.25	5.06	52.39	2.07	35.23	4,891	8,800
General average	....	90.09	9.91	4.61	48.71	2.29	34.48	4,452	8,073

[a] Vermont Agr. Exper. Sta. Bull. 165, p. 219, 1912.

VIRGINIA AND NORTH CAROLINA.

Analyses of peat and muck.

[H. M. Cooper, Bureau of Mines, analyst.]

Locality.	Sample No.	Hole.	Condition of sample.[a]	Proximate.			Ultimate.			Calorific value.	
				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Nitrogen.	Calories.	British thermal units.
VIRGINIA.											
Norfolk County	1	A	1	14.01	45.42	33.92	6.64	0.31	1.73	4,690	8,442
			2	....	52.82	39.46	7.72	.36	2.01	5,454	9,818
Do	2	A	1	32.93	42.42	19.62	5.03	.23	1.38	3,655	6,578
			2	....	63.25	29.25	7.50	.34	2.06	5,449	9,808
Do	3	B	1	17.93	46.57	20.15	15.35	.19	1.31	4,052	7,293
			2	....	56.74	24.56	18.70	.23	1.60	4,937	8,886
Do	4	B	1	18.88	47.55	18.49	15.08	.19	1.27	4,021	7,238
			2	....	58.62	22.79	18.59	.23	1.57	4,957	8,923
Do	5	D	1	9.38	48.05	18.72	23.85	.28	1.67	3,881	6,985
			2	....	53.02	20.66	26.32	.31	1.84	4,282	7,708
Nansemond County	6	F	1	6.43	30.32	10.92	52.33	.25	1.07	....	....
			2	....	32.40	11.67	55.93	.27	1.14	....	....
NORTH CAROLINA.											
Currituck County	7	J	1	8.23	52.05	33.54	6.18	.26	1.60	5,163	9,294
			2	....	56.72	36.55	6.73	.28	1.74	5,626	10,127

[a] 1, As received in the laboratory. 2, Moisture free.

Analyses of peat from Pasquotank County, N. C.[a]

[F. M. Stanton, U. S. Geol. Survey, analyst.]

Laboratory No.	Condition of sample.[b]	Proximate.			Ultimate.						Air-drying loss.	Calorific value.	
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
[c] 5585	1	85.12	7.72	4.29	2.87	0.33	10.06	7.06	0.25	79.43	83.20	682	1,228
....	2	....	51.88	28.83	19.29	2.22	4.03	47.45	1.08	25.33	....	4,583	8,249

[a] Davis, C. A., The uses of peat for fuel and other purposes: Bur. Mines Bull. 16, p. 199, 1911.

[b] 1, Native peat. 2, Moisture-free peat.

[c] Sack sample.

WISCONSIN.

Analyses of peat and muck.[a]

[Survey of 1903.]

Location (nearest town or city).	Deposit No.	Sample No.	As received.	Moisture-free.				Combustible contents.		
			Moisture.	Volatile matter.	Fixed carbon.	Ash.	British thermal units.	Volatile matter.	Fixed carbon.	British thermal units.
Stoughton	1	1	69.7	63.3	25.3	11.4	9,320	71.5	28.5	10,500
Do	1	2	65.2	63.1	24.5	12.4	8,980	72.0	28.0	10,260
Do	1	3	87.0	62.4	26.5	11.1	8,929	70.4	29.8	10,000
Do	1	4	74.4	59.3	20.5	20.2	6,190	74.4	25.7	7,760
Do	1	5	85.3	63.3	23.6	13.1	8,570	73.9	26.1	9,880
Whitewater	2	1	69.4	38.4	16.9	44.7	6,040	69.5	30.6	10,900
Do	2	2	85.5	60.4	27.8	11.8	9,440	68.5	31.6	10,700
Do	2	3	82.8	58.2	26.6	15.2	9,040	68.7	31.4	10,650
Do	2	4	[b]33.4	57.4	25.4	17.2	9,370	69.4	30.7	11,300
Do	2	5	[b]14.0	59.7	29.4	10.9	8,600	67.0	33.0	9,695
Do	3	1	83.0	52.2	28.3	19.5	8,060	64.9	35.2	10,000
Do	3	2	82.9	62.0	28.7	9.3	8,370	68.4	31.6	9,250
Do	3	3	80.7	57.2	27.0	15.8	8,600	68.0	32.0	10,200
Do	4	1	81.1	55.7	25.1	19.2	7,920	69.0	31.1	9,800
Do	4	2	80.7	53.1	32.3	14.6	8,490	62.3	37.8	9,900
Lake Beulah	5	1	[b]58.5	58.5	28.6	12.9	8,280	67.3	32.8	9,500
Do	5	2	[b]14.9	56.7	30.9	12.4	8,870	64.7	35.2	10,100
Do	5	3	83.5	59.3	27.5	13.2	8,870	68.1	31.9	10,200
Dousman	6	1	......	......	......	......	......	......	......	......
Madison	7	1	......	......	......	......	......	......	......	......
Glenbeulah	8	1	88.2	64.5	29.0	6.5	9,060	69.0	31.0	9,700
Do	8	2	89.4	68.7	25.7	5.6	10,600	72.9	27.1	11,209
Do	8	3	90.5	67.2	25.3	7.5	9,500	72.7	27.3	10,300
Do	8	4	90.6	63.8	24.8	11.4	8,500	72.1	27.9	9,600
Do	8	5	89.4	65.3	23.6	11.1	8,650	73.5	26.5	9,700
Medina	9	1	83.8	63.8	28.6	7.6	8,700	69.0	......	9,450
Do	9	2	69.1	43.4	14.2	42.4	3,700	75.3	24.7	6,300
Do	9	3	88.8	59.8	29.4	10.8	8,400	67.1	32.9	9,500
Do	9	4	83.4	61.7	30.0	8.3	9,800	67.2	32.8	10,600
Do	9	5	83.5	56.2	29.7	14.1	8,600	65.5	34.5	9,900
Do	9	6	80.0	62.6	19.3	18.1	7,300	76.5	23.5	8,900
Fond du Lac	10	1	83.1	61.8	28.8	11.4	8,800	69.9	30.1	9,900
Do	10	2	81.4	60.6	24.0	15.4	8,800	71.7	28.3	10,400
Do	10	3	79.5	43.7	29.8	26.5	4,800	59.5	40.5	6,600
Do	10	4	80.1	55.4	27.5	17.1	6,900	66.9	33.1	8,300
Do	10	5	84.0	61.1	29.0	9.9	8,700	68.0	32.0	9,600
Do	10	6	88.9	70.5	21.8	7.7	10,300	76.5	23.5	11,100
Chester	11	1	79.0	55.3	28.4	16.3	7,300	66.2	33.8	8,770
Do	11	2	77.7	48.0	23.3	28.7	7,690	66.4	33.6	10,600
Do	11	3	78.6	52.7	25.4	21.9	7,100	67.5	32.5	9,100
Do	11	4	77.9	47.9	23.8	28.3	6,700	66.9	33.1	9,400
Do	11	5	82.0	58.1	17.8	24.1	6,870	76.6	23.4	9,000
Mendota	12	1	86.4	64.1	25.1	10.8	8,700	72.8	27.2	9,800
Do	12	2	86.6	60.1	25.5	14.4	8,400	70.4	29.6	9,800
Do	12	3	86.5	57.7	26.4	15.9	8,100	68.6	31.4	9,600
Do	12	4	85.8	56.9	25.9	17.2	7,800	68.7	31.3	9,500
Do	12	5	85.4	54.0	31.8	14.2	7,800	63.0	37.0	9,200
Do	12	6	88.6	63.1	27.6	9.3	9,200	69.6	30.4	10,100
Markesan	13	1	85.1	60.8	30.1	9.1	9,500	67.1	32.9	10,400
Do	13	2	67.0	45.9	7.1	47.0	......	......	......	......
Marshall	14	1	[b]18.6	60.9	27.9	11.2	9,000	68.8	31.4	10,200
Rhinelander	15	1	89.3	66.2	28.3	5.5	10,600	70.1	29.9	11,300
Do	15	2	91.4	66.3	27.3	6.4	9,600	70.9	29.1	10,300
Do	15	3	89.4	71.3	22.8	5.9	9,200	75.8	24.2	9,800
Do	15	4	90.7	66.0	28.5	5.5	9,960	69.9	30.1	10,500
Do	16	1	......	......	......	......	......	......	......	......
Do	17	1	......	......	......	......	......	......	......	......

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[a] Huels, F. W., The peat resources of Wisconsin: Wisconsin Geol. and Nat. Hist. Survey Bull. 45, Econ. Series 20, pp. 149–151, 1915.

[b] Partly air-dried before the moisture content was determined.

Analyses of peat and muck.

[Survey of 1908.]

Location (nearest town or city).	Deposit No.	Air-drying loss.	Air-dried.						As received.						Moisture-free.				
			Moisture.	Volatile matter.	Fixed carbon.	Ash.	British thermal units.	Sulphur.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	British thermal units.	Sulphur.	Volatile matter.	Fixed carbon.	Ash.	British thermal units.	Sulphur.
Madison	301	61.50	9.26	47.18	17.89	25.67	6,250	0.42	65.07	18.16	6.89	9.88	2,407	0.16	51.99	19.73	28.28	6,890	0.45
Do.	301	82.00	8.60						[a]83.55										
Do.	302	68.50	8.99	50.82	21.42	18.77	6,943	.38	71.33	16.01	6.75	5.91	2,187	.12	55.84	23.55	20.61	7,628	.42
Do.	302	84.30	6.92						[a]85.39										
Fond du Lac	303 B	73.80	11.99	51.03	21.75	15.23	7,169	.66	76.94	13.37	5.70	3.99	1,879	.17	57.98	24.72	17.30	8,149	.74
Do.	303 B	85.00	7.72						[a]86.16										
Do.	303 A	6.60	9.95	48.14	25.14	16.77	7,468	.79	15.89	44.96	23.49	15.66	6,975	.74	53.45	27.93	18.62	8,293	.88
Waupaca	304	19.40	6.95	54.23	23.44	15.38	7,614	.37	25.00	43.71	18.89	12.40	6,136	.30	58.29	25.18	16.53	8,181	.40
Do.	304	85.60	6.90						[a]86.59										
Do.	305	13.00	6.62	55.31	13.63	24.44	6,970	......	18.76	48.12	11.86	21.26	6,064	......	59.23	14.60	26.17	7,465	......
Do.	305	94.90	7.64						[a]95.29										
Kiel	306	16.40	7.70	48.38	16.00	27.92	6,107	1.51	22.84	40.45	13.37	23.34	5,107	1.26	52.42	17.33	30.25	6,619	1.63
Do.	306	83.60	7.74						[a]84.82										
Do.	307	28.40	6.82	52.30	21.42	19.46	7,256	1.51	33.28	37.45	15.34	13.39	5,195	1.08	56.13	22.99	20.88	7,787	1.62
Do.	308	20.40	7.79	53.04	20.85	18.32	7,119	.82	26.60	42.22	16.60	14.58	5,666	.65	57.52	22.62	19.86	7,720	.89
Do.	308	86.90	9.25						[a]88.11										
Do.	309	......	8.22	58.07	23.21	10.50	8,032	.64	20.43	50.35	20.12	9.10	6,964	.55	63.28	25.28	11.44	8,753	.69
Do.	309	90.30	7.79						[a]91.06										
Bloomer	310	72.90	11.76	41.80	15.30	31.14	5,503	.28	76.09	11.33	4.14	8.44	1,490	.08	47.39	17.31	35.30	6,233	.33
Do.	310	80.10	9.15						[a]81.92										
Do.	311	75.80	10.35	49.26	24.74	15.65	7,929	.21	78.30	11.92	5.99	3.79	1,919	.05	54.93	27.60	17.47	8,842	.23
Do.	311	82.20	7.67						[a]83.57										
Ashland	312	45.30	6.82	26.69	6.38	60.11	2,984	.24	49.03	14.60	3.49	32.88	1,633	.13	28.64	6.85	64.51	3,202	.26
Do.	312	61.30	4.57	22.60	5.64	67.19	......	.18	[a]63.07	8.75	2.18	26.00	......	.07	23.69	5.91	70.40	......	.19
Hayward	313	9.00	10.21	50.77	25.06	13.96	7,866	.26	18.29	46.20	22.81	12.70	7,159	.24	56.54	27.92	15.54	8,761	.29
Do.	313	90.80	6.66						[a]91.41										
Do.	314	11.30	7.71	51.13	20.07	21.09	7,411	.39	18.14	45.35	17.80	18.71	6,574	.35	55.40	21.74	22.86	8,028	.43
Do.	314	91.10	3.93						[a]91.45										
New Auburn	315	4.90	7.66	53.55	25.48	13.31	8,222	.20	12.18	50.93	24.23	12.66	7,819	.19	57.99	27.59	14.42	8,905	.22
Do.	315	92.50	4.95						[a]92.87										
Cameron	316	9.30	5.21	60.08	26.78	7.93	8,716	.28	14.03	54.49	24.29	7.19	7,906	.25	63.38	28.26	8.36	9,196	.29
Do.	316	90.50	7.22						[a]91.19										
Ladysmith	317	7.80	3.85	54.00	20.98	21.17	7,646	.24	11.35	49.79	19.34	19.52	7,051	.22	56.16	21.82	22.02	7,952	.25
Do.	317	88.50	5.31						[a]89.11										
Heafford Junction	318	10.10	4.07	53.63	20.44	21.86	7,722	.23	13.76	48.21	18.38	19.65	6,943	.21	55.90	21.31	22.79	8,051	.24
Do.	318	93.70	5.08						[a]94.02										

Minocqua	319	15.10	5.72	50.08	20.82	23.38	7,456	.28	19.96	42.52	17.67	19.85	6,331	.24	53.12	22.08	24.80	7,909	.30
Do.	319	83.20	4.12						[a]83.89										
Do.	320	9.20	4.58	51.92	18.82	24.68	7,236	.50	13.36	47.14	17.09	22.41	6,570	.45	54.41	19.72	25.87	7,583	.52
Do.	320	92.50	4.36						[a]92.83										
Lac du Flambeau	321	10.80	2.68	53.52	22.84	20.96	8,417	.16	13.19	47.47	20.37	18.70	7,508	.14	54.99	23.47	21.54	8,649	.16
Do.	321	83.70	5.02						[a]84.52										
Powell	322	11.40	6.56	53.04	25.32	15.08	7,627	.89	17.21	46.99	22.44	13.36	6,757	.79	56.76	27.10	16.14	8,161	.95
Do.	322	87.50	6.29						[a]88.29										
Glidden	323	9.00	4.62	58.33	25.76	11.29	8,723	.22	13.20	58.08	23.45	10.27	7,938	.20	61.15	27.02	11.83	9,146	.23
Do.	323	91.80	6.33						[a]92.32										
Park Falls	324	8.00	3.99	42.81	18.95	34.25	6,291	.30	11.67	39.39	17.43	31.51	5,787	.28	44.59	19.74	35.67	6,552	.32
Do.	324	71.10	5.63						[a]72.73										
Kewaunee	325	6.10	8.96	53.94	23.60	13.50	7,290	.47	14.51	50.65	22.16	12.68	6,845	.44	59.25	25.92	14.83	8,006	.51
Do.	325	86.70	7.88						[a]87.85										
Algoma	326	3.50	7.51	38.52	15.19	38.78	5,445	.26	10.75	37.17	14.66	37.42	5,254	.25	41.65	16.42	41.93	5,886	.28
Do.	326	67.60	7.63						[a]70.07										
Sturgeon Bay	327	6.30	9.01	54.73	16.20	20.06	7,186	.77	14.74	51.28	15.18	18.80	6,734	.72	60.15	17.80	22.05	7,898	.84
Do.	327	91.40	8.77						[a]92.15										
Peshtigo	328	75.10	5.05	43.29	18.69	32.95	6,012	.66	76.36	10.78	4.66	8.20	1,498	.16	45.60	19.71	34.69	6,334	.68
Pembine	329	6.80	9.25	50.60	23.15	17.00	7,112	1.51	15.42	47.16	21.58	15.84	6,628	1.41	55.75	25.52	18.73	7,835	1.67
Do.	329	82.80	6.80						[a]83.97										
Gagen	330	10.30	5.71	59.19	26.13	8.97	8,856	.21	15.42	53.09	23.44	8.05	7,943	.19	62.77	27.71	9.52	9,391	.22
Do.	330	86.40	5.74						[a]87.18										
Eagle River	331	11.20	5.21	60.14	24.06	10.59	8,869	.26	15.83	53.40	21.37	9.40	7,875	.23	63.44	25.39	11.17	9,356	.27
Do.	331	85.70	5.13						[a]86.43										
Antigo	332	78.60	7.67	43.04	19.47	29.82	5,870	.60	80.24	9.21	4.17	6.38	1,256	.13	46.61	21.10	32.29	6,358	.66
Mountain	333	12.90	7.95	54.46	25.47	12.12	7,191	.69	19.82	47.43	22.19	10.56	6,264	.60	59.15	27.68	13.17	7,812	.75
Do.	333	86.60	7.24						[a]87.57										

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[a] Shipped to the laboratory in air-tight containers.

Analyses of peat and muck.[a]

[F. M. Stanton, U. S. Geological Survey, analyst.]

Locality.	Laboratory No.	Condition of sample.[b]	Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
ASHLAND COUNTY.														
Glidden	c 6424	1	92.32									91.80		
	d 6423	1	13.20	53.08	23.45	10.27	0.20					9.00	4,410	7,938
		2		61.15	27.02	11.83	.23						5,081	9,146
CHIPPEWA COUNTY.														
New Auburn	c 6389	1	92.87									92.50		
	d 6384	1	12.18	50.93	24.23	12.66	.19					4.90	4,344	7,819
		2		57.99	27.59	14.42	.22						4,947	8,905
DANE COUNTY.														
Madison (University Bay Marsh)	c 6282	1	85.39									84.30		
	d 6278	1	71.33	16.01	6.75	5.91	.12					68.50	1,215	2,187
		2		55.84	23.55	20.61	.42						4,238	7,628
Madison	c 6346	1	81.92									80.10		
	d 6345	1	76.09	11.33	4.14	8.44	.08					72.90	828	1,490
		2		47.39	17.31	35.30	.33						3,463	6,233
	c 6348	1	83.57									82.20		
	d 6347	1	78.30	11.92	5.99	3.79	.05					75.80	1,066	1,919
		2		54.93	27.60	17.47	.23						4,912	8,842
	c 6350	1	63.07	8.75	2.18	26.00	.07					61.30	535	963
		2		23.69	5.91	70.40	.19						1,449	2,608
	d 6349	1	49.03	14.60	3.49	32.88	.13					45.30	907	1,633
		2		28.64	6.85	64.51	.26						1,779	3,202
Mendota, 1 mile northwest of	c 6281	1	83.55									82.00		
	d 6277	1	65.07	18.16	6.89	9.88	.16					61.50	1,337	2,407
		2		51.99	19.73	28.28	.45						3,828	6,890
DOOR COUNTY.														
Sturgeon Bay	c 6472	1	92.15									91.40		
	d 6471	1	14.74	51.28	15.18	18.80	.72					6.30	3,741	6,734
		2		60.15	17.80	22.05	.84						4,388	7,898

FOND DU LAC COUNTY.														
Fond du Lac, 7 miles west of (remains of peat briquets)	d 6279	1	15.89	44.96	23.49	15.66	.74					6.60	3,875	6,975
		2		53.45	27.93	18.62	.88						4,607	8,293
Fond du Lac, 7 miles west of	c 6283	1	86.16									85.00		
	d 6280	1	76.94	13.37	5.70	3.99	.17	9.57	10.87	0.68	74.72	73.80	1,044	1,879
		2		57.98	24.72	17.30	.74	4.42	47.14	2.95	27.45		4,527	8,149
IRON COUNTY.														
Powell	c 6422	1	88.29									87.50		
	d 6421	1	17.21	46.99	22.44	13.36	.79					11.40	3,754	6,757
		2		56.76	27.10	16.14	.95						4,534	8,161
KEWAUNEE COUNTY.														
Algoma	c 6465	1	70.07									67.60		
	d 6464	1	10.75	37.17	14.66	37.42	.25					3.50	2,919	5,254
		2		41.65	16.42	41.93	.28						3,270	5,886
Kewaunee	c 6463	1	87.85									86.70		
	d 6462	1	14.51	50.65	22.16	12.68	.44					6.10	3,803	6,845
		2		59.25	25.92	14.83	.51						4,448	8,006
LANGLADE COUNTY.														
Antigo	c 6527	1	80.24	9.21	4.17	6.38	.13					78.60	698	1,256
		2		46.61	21.10	32.29	.66						3,532	6,358
LINCOLN COUNTY.														
Heafford Junction	c 6412	1	94.02									93.70		
	d 6411	1	13.76	48.21	18.38	19.65	.21					10.10	3,857	6,943
		2		55.90	21.31	22.79	.24						4,473	8,051
MANITOWOC COUNTY.														
Kiel, 7 miles northeast of	c 6293	1	84.82									83.60		
	d 6292	1	22.84	40.45	13.37	23.34	1.26					16.40	2,837	5,107
		2		52.42	17.33	30.25	1.63						3,677	6,619
	d 6294	1	33.28	37.45	15.34	13.93	.08					28.40	2,886	5,195
		2		56.13	22.99	20.88	1.62						4,326	7,787
	c 6296	1	88.11									86.90		
	d 6295	1	26.60	42.22	16.60	14.58	.65					20.40	3,148	5,666
		2		57.52	22.62	19.86	.89						4,289	7,720
MARINETTE COUNTY.														
Pembine	c 6508	1	83.97									82.80		
	d 6507	1	15.42	47.16	21.58	15.84	1.41	5.51	39.62	1.45	36.17	6.80	3,682	6,628
		2		55.75	25.52	18.73	1.67	4.49	46.84	1.71	26.56		4,353	7,835
Peshtigo	c 6515	1	76.36	10.78	4.66	8.20	.16					75.10	832	1,498
		2		45.60	19.71	34.69	.68						3,519	6,334

[a] Davis, C. A., The uses of peat for fuel and other purposes: Bur. Mines Bull. 16, pp. 200–203, 1911.

[b] 1, Native peat. 2, Moisture-free peat.

[c] Bottle sample.

[d] Sack sample.

Analyses of peat and muck—Continued.

Locality.	Laboratory No.	Condition of sample.	Proximate.				Ultimate.					Air-drying loss.	Calorific value.	
			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
OCONTO COUNTY.														
Cameron	a 6390	1	91.19									90.50		
	b 6385	1	14.03	54.49	24.29	7.19	0.25					9.30	4,392	7,906
		2		63.38	28.26	8.36	.29						5,109	9,196
Mountain	a 6526	1	87.57									86.60		
	b 6525	1	19.82	47.43	22.19	10.56	.60					12.90	3,480	6,264
		2		59.15	27.68	13.17	.75						4,340	7,812
ONEIDA COUNTY.														
Gagen	a 6510	1	87.18									86.40		
	b 6509	1	15.42	53.09	23.44	8.05	.19					10.30	4,413	7,943
		2		62.77	27.71	9.52	.22						5,217	9,391
PRICE COUNTY.														
Parkfalls	a 6426	1	72.73									71.10		
	b 6425	1	11.67	39.39	17.43	31.51	.28					8.00	3,215	5,787
		2		44.59	19.74	35.67	.32						3,640	6,552
RUSK COUNTY.														
Ladysmith	a 6391	1	89.11									88.50		
	b 6386	1	11.35	49.79	19.34	19.52	.22					7.80	3,917	7,051
		2		56.16	21.82	22.02	.25						4,418	7,952
SAWYER COUNTY.														
Hayward	a 6387	1	91.41									90.80		
	b 6382	1	18.29	46.20	22.81	12.70	.24	5.88	41.67	1.57	37.94	9.00	3,977	7,159
		2		56.54	27.92	15.54	.29	4.71	51.00	1.92	26.54		4,867	8,761
	a 6388	1	91.45									91.10		
	b 6383	1	18.14	45.85	17.80	18.71	.35					11.30	3,652	6,574
		2		55.40	21.74	22.86	.43						4,460	8,028
SHEBOYGAN COUNTY.														
Kiel, 6 miles southwest of	a 6298	1	91.06									90.30		
	b 6297	1	20.43	50.35	20.12	9.10	.55					13.30	3,869	6,964
		2		63.28	25.28	11.44	.69						4,863	8,753
VILAS COUNTY.														
Eagle River	a 6512	1	86.43									85.70		
	b 6511	1	15.83	53.40	21.37	9.40	.23					11.20	4,375	7,875
		2		63.44	25.39	11.17	.27						5,198	9,356

Lac du Flambeau	[a] 6420	1	84.52	....	....	....	....	....	....	....	....	83.70	....	....
	[b] 6419	1	13.19	47.74	20.37	18.70	14	....	....	....	....	10.80	4,171	7,508
		2	....	54.99	23.47	21.54	.16	....	....	....	....	....	4,805	8,649
Minocqua	[a] 6414	1	83.89	....	....	....	....	....	....	....	....	83.20	....	....
	[b] 6413	1	19.96	42.52	17.67	19.85	.24	....	....	....	....	15.10	3,517	6,331
		2	....	53.12	22.08	24.80	.30	....	....	....	....	....	4,394	7,909
	[a] 6416	1	92.83	....	....	....	....	....	....	....	....	92.50	....	....
	[b] 6415	1	13.36	47.14	17.09	22.41	.45	....	....	....	....	9.20	3,650	6,570
		2	....	54.41	19.72	25.87	.52	....	....	....	....	....	4,213	7,583
WAUPACA COUNTY.														
Waupaca, half a mile north of	[a] 6289	1	86.59	....	....	....	....	....	....	....	....	85.60	....	....
	[b] 6288	1	25.00	43.71	18.89	12.40	.30	....	....	....	....	19.40	3,409	6,136
		2	....	58.29	25.18	16.53	.40	....	....	....	....	....	4,545	8,181
Waupaca, 3 miles northwest of	[a] 6291	1	95.29	....	....	....	....	....	....	....	....	94.90	....	....
	[b] 6290	1	18.76	48.12	11.86	21.26	.57	6.09	32.71	2.30	37.07	13.00	3,369	6,064
		2	....	59.23	14.60	26.17	.70	4.94	40.26	2.83	25.10	....	4,147	7,465

[a] Bottle sample.

[b] Sack sample.

CONCLUSIONS.

Minnesota, Wisconsin, and Michigan contain a large quantity of high-grade peat. The average nitrogen content of 246 samples, collected from widely scattered localities in Minnesota, was 2.25 per cent and the average calorific value of the moisture-free peat was 8,329 British thermal units. The average composition of Wisconsin peat and muck is shown by the following table, compiled in part from the foregoing analyses:

Average composition of peat and muck from Wisconsin.

Moisture (native)	84.5
Moisture (air-dried)	26.9
Volatile matter	56.4
Fixed carbon	24.0
Ash	19.5
Sulphur	.6
Carbon (combined)	46.3
Hydrogen	4.6
Oxygen	26.4
Nitrogen	2.4

Although the peat deposits of Michigan have not been so thoroughly tested as those of Minnesota and Wisconsin, they are of high quality.

Large quantities of good peat, suitable for fertilizer, fuel, packing material, and other products are found in all the States shown in the tables. Specific localities throughout the United States where peat suitable for the purposes mentioned may be obtained are listed on pages 91–202.

Some of the peat deposits of New York and northern New Jersey are similar in chemical properties to those of Wisconsin and Michigan and are well adapted for the manufacture of peat products.

The peats of many deposits in Iowa, Illinois, and Pennsylvania contain too much ash for use as fuel, though they may be used for making fertilizer and packing material. Of 266 samples of Iowa peat selected at random and analyzed, only 15 contained less than 25 per cent of inorganic material and only 1 less than 15 per cent. The peats of the Illinois and Pennsylvania deposits are also relatively impure. However, the average nitrogen content of the Illinois peat as shown by analyses of samples is 2.65 per cent, and the peats of Iowa and Pennsylvania probably contain about 2 per cent, which is the general average. Five samples of Illinois peat contain more than 3 per cent of nitrogen and one from the Duck Lake deposit in that State contains 3.84 per cent, an unusually high percentage for raw peat.

The average nitrogen content of peat from Indiana, as shown by the foregoing analyses, is 2.8 per cent, and the average calorific value

is 8,552 British thermal units. The peat of Ohio ranges in content of nitrogen from 1.01 to 3.60 per cent and in calorific value (moisture-free peat) from 7,132 to 9,736 British thermal units. It is therefore apparent that the deposits of these States contain peat well adapted to use both as fertilizer and as fuel.

Aside from some of the peat deposits of Massachusetts and Rhode Island and a few in other States that contain a large quantity of ash, most of the peat in the New England region is of good quality. In 69 samples of peat from Maine the range in calorific value of the moisture-free material was from about 8,000 to 9,800 British thermal units. Maine also contains an immense quantity of sphagnum moss and moss peat suitable for surgical dressings, packing material, and stable litter.

The peat deposits of the Atlantic coastal region south of northern New Jersey, as well as those in the Pacific Coast States, are variable in quality. The salt-marsh peat is generally too impure for commercial use, but some of the inland swamps, like the Dismal Swamp of Virginia and North Carolina and the Everglades of Florida, contain good peat. In fact, peat from Florida compares favorably with peat from any other part of the country. It is equal to the best peat in the Great Lakes States and is higher in calorific value and lower in ash than much of the peat of New England.

USES OF PEAT.

AGRICULTURAL USES.

The uses of peat in agriculture are manifold. Prepared peat is used directly as a fertilizer, as an ingredient of commercial fertilizers and stock feed, as stable litter, and as an absorbent and disinfectant. Peat soils are well adapted to the growth of certain crops.

FERTILIZER.

GENERAL FEATURES.

The peat deposits of the United States form one of the few extensive known domestic sources of nitrogen that can be converted into plant food at a price low enough to be economically used by the farmers. The average nitrogen content of domestic air-dried peat is about 2 per cent, although many peats contain more than this quantity. This nitrogen may be recovered in the form of ammonium sulphate by the methods considered on pages 72–73 or may be made available for plant food without extracting it from the peat. Arguments are often advanced against the direct use of peat as a source of nitrogen in soil fertilization, because not all the nitrogen it con-

tains, as shown by chemical analysis, is readily available for plant food, but this criticism seems to be based on a misconception of the nature of the peat. It is true that only a part of the nitrogen shown by analysis can be immediately used as food by plants, but it is equally true that a chemical analysis of peat is not a fair test of its value as a fertilizer and that the total quantity of potential soluble nitrogen formed and released by bacterial action from time to time after the peat has been applied to the soil is in the aggregate often greater than the percentage found in some commercial fertilizers. Fortunately all the nitrogen in peat is not soluble at one time, or it would leach out, and the potentially rich black peat soils of this country would become unproductive.

Bacterized peat as a direct fertilizer is said to be even a more prolific source of soluble nitrogen than the crude material. The following method of increasing the nitrogen content of soils by means of peat is proposed by Bottomley:[5]

> It is well known that if peat is exposed to the air for several years it is neutralized by the formation of ammonia, and a large proportion of the insoluble material is converted into food available for plant life. By inoculating the peat with aerobic bacteria it is found possible greatly to accelerate this change and to increase materially the quantity of plant food. The problem, however, was not to discover a fertilizer, but to find a medium in which nitrogen-fixing organisms could be cultivated and placed on the soil. This medium is found in the peat treated with aerobic bacteria. To prepare it for inoculation the peat is kept moist at a temperature of 25° C. for about a week. Steam is then forced through it to insure that all organisms, bacterial or otherwise, are destroyed, and the result is a sterile medium, neutral or slightly alkaline, suitable for the cultivation of plants or of nitrifying bacteria. The sterilized peat is then inoculated with a mixed culture of *Bacillus radicicola* and *Azotobacter chroococcum*, which multiply rapidly and soon permeate the entire culture bed. After complete saturation the bacterial growth is arrested by drying the peat, and it is then ready for use.

It is said that the bacteria in this material enrich the soil to which they are applied by extracting nitrogen from the air and converting it into soluble plant food, and that owing to continuous bacterial action frequent subsequent treatment is unnecessary. According to some reports, however, the process seems to be of doubtful value.

Another process for the commercial application of bacteria to soil fertilization is reported by John N. Hoff, of New York. According to his method the peat is cultivated for several seasons, excavated, sun dried, neutralized or made slightly alkaline, and used for a carrier and energizer of several varieties of nitrogen-fixing bacteria. When mixed with certain phosphates and applied to the soil these

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[5] Knox, G. D., The spirit of the soil, 242 pp., 17 figs., London, Constable & Co. (Ltd.), 1916.

bacteria are said to stimulate plant growth and to react upon and release phosphorus from insoluble chemical combinations.

According to reports bacterized peat is being used commercially in England. It is said that larger crops have been grown upon soil enriched by bacterized peat in the United States than could have been obtained from the same land treated with commercial fertilizer.

Whether used as a direct fertilizer or as an ingredient of commercial ferilizers, peat when properly treated is valuable both chemically and physically. Its content of soluble nitrogen is immediately available for plant food, and it is potentially rich in this element, which gradually forms soluble compounds and is released; it supplies humus, a vital requirement for plant life under natural conditions; on account of its black color it absorbs heat; soils to which it is applied are made friable and can be readily worked; and its water-holding properties are proverbial. Because of these characteristics peat is being used more and more in soil cultivation.

For those who propose to enter this branch of the peat industry it is suggested that caution be observed in selecting a suitable deposit. Before any money is invested a careful survey should be made of the prospective deposit to insure that there is a sufficient quantity of peat to justify the erection of a plant. Typical samples should be taken from different parts of the deposit and examined to determine whether the material is chemically adapted for fertilizer. Many peats are acid when first taken from the bog or swamp.

Black, well-humified peat is most satisfactory for soil fertilization. Only bogs containing peat that is rich in nitrogen should be selected. The acidity of the raw peat must be corrected by thorough aeration and liming before any attempt is made to market it as a fertilizer for ordinary crops. One of the great handicaps of the peat-fertilizer industry in this country has been the lack of uniformity in its product, and as the success of a plant depends upon the character of the peat used, too much caution can not be observed in the selection of the material.

METHODS OF PREPARATION.

Equally important as the kind of peat are the process and machinery employed in treating it. The deposit must first be drained and cleared of trees, brush, and turf. Cultivation of the peat for several seasons will correct the acidity and afford means for determining its agricultural value. After the upper layer has been plowed, disked, and harrowed, the peat is excavated to a depth of about 3 feet and left in windrows on the surface of the bog. When the moisture has been reduced to about 50 per cent by air-drying the material is scraped into piles, loaded into cars, and hauled to a stock pile. After aerobic fermentation is well advanced, the material is

run through heated rotary driers until the moisture is lowered to 10 per cent, screened, and cooled. The resulting product is used as a nitrogenous ingredient of commercial fertilizers. This material may be further enriched with nitrogen by liming and appropriate inoculation, and if a complete direct fertilizer is desired potash, phosphates, and other minerals are mixed with it.

The outdoor equipment consists essentially of agricultural implements—excavators, scrapers, loaders, some light rails, a few cars and small locomotives, an elevator to raise the peat to the top of the stock pile, and a conveyer for transporting it to the driers. If possible the excavators, scrapers, and loaders should be electrically propelled and operated with caterpillar drives, as machinery so equipped gives little trouble on boggy surfaces. The indoor equipment consists of engines, boilers, dynamos, rotary driers, and sifters. The building containing the drying plant should be fireproof and should be located as near the deposit as possible.

In order that the plant may run throughout the year, it is the best practice to excavate and pile up as much peat as possible during the air-drying season and to complete the drying artificially when the material is needed. By adopting the process and equipment described lost motion is minimized and a large proportion of the water in the peat is eliminated in the field.

Peat fertilizer may be cheaply prepared by farmers owning small bogs by composting the raw peat with manure, and after the bacteria have saturated the mixture it may be applied to the soil in the same way as manure. Land that is deficient in humus and nitrogen will thus be materially benefited.

PEAT SOILS.

GENERAL FEATURES.

Peat soil, when properly treated, is one of the most fertile types of soil in this country. Owing to the abundance of well-drained land that could be more readily tilled, areas of peat and muck have in times past been neglected, but with the rapid increase of our population and the necessity for intensive soil cultivation the attention of agriculturists and others is now being directed to these lands. In the eastern section of this country there are approximately 15,000,000 acres of peat and muck land, which supports a growth of shrubs, tamarack, white cedar, birch, water maple, gum, and cypress and only about 750,000 acres, or 5 per cent of the total area, has been reclaimed for agricultural purposes. Franklin K. Lane, in advocating the reclamation of the swamp and cut-over timber lands of the United States and their sale on the basis of deferred payments

A. EXCELLENT STAND OF CORN RAISED ON RECLAIMED PEAT LAND AT BIG ISLAND, ORANGE COUNTY, N. Y.

B. DRY HAND-CUT PEAT FUEL AND SLANE WITH WHICH IT IS EXCAVATED.

COMMERCIAL PRODUCTS OF PEAT.

o men who had done military service, said in substance in a statenent for the press:

> There are approximately 200,000,000 acres of cut-over or logged-off timberland in the eastern half of the United States, and, overlapping to a certain extent the cut-over lands, some 80,000,000 acres of swamp land, located largely in the southeastern section of the country. To the ordinary observer the reclamation of these waste areas may seem difficult. The soil, however, is in many localities very fertile. For many years leaf mold containing humus has been accumulating, and once the stumps have been blown out and the land cleared of brush and brought under the plow, it is believed that these lands will prove among the most fertile of our agricultural resources. Like the Dismal Swamp in Virginia or the Everglades in Florida, most of the swamp land in its present condition is unfit for human inhabitants. Consider this land cleared of its timber, adequately drained, and intensively cultivated, and some idea of its possibilities for the production of food will be obtained.

Raw peat soils, though too acidic for ordinary farming, after they have been drained, cleared, freely aerated, and properly fertilized, are especially well adapted for the production of vetch, redtop, millet, buckwheat, oats, corn, rye, the potato, the cranberry, the blueberry, the strawberry, and other acid-tolerant crops.[6] (See Pl. IV, *A*.) If properly treated with potash salts and with lime they are neutralized or made slightly alkaline and should then yield good crops of red clover, timothy, bluegrass, wheat, rutabagas, and other alkaline or neutral soil crops. The greatest values derived from the cultivation of peat, however, have arisen from its use as a truck crop soil. According to the Bureau of Soils,[7] cabbage, onions, celery, lettuce, spinach, carrots, beets, turnips, and peppermint are the most valuable crops that are grown on treated areas of peat. The acreage values of these crops so far surpass those of the general farm crops that their cultivation should be made the object of the reclamation of any large areas of peat.

The fertility of peat soil is chiefly due to its content of nitrogen and humus, to its affinity for moisture, and to its blackness, which enables it to absorb heat. For the profitable production and sale of both general and special crops it is desirable that the areas of peat which are close to large city markets and accessible to good transportation and cheap labor should be reclaimed first.

The first attempts to use peat lands for the growth of crops were made in the older agricultural districts of the Eastern States, notably New York and New Jersey. Some of the most productive farm lands in those States were formerly peat bogs and swamps. The truck farm of John N. Hoff near Great Meadows, Warren County,

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[6] Coville, F. V., The agricultural utilization of acid lands by means of acid-tolerant crops: U. S. Dept. Agr. Bull. 6, 1913.

[7] U. S. Bur. Soils Circ. 65, pp. 13, 14, 1912.

N. J.; the well-known onion farms of the Wallkill River Valley, Orange County, N. Y.; and the Oak Orchard lands north of Batavia, N. Y., are reclaimed peat deposits. Thousands of acres of land in these States now under intensive cultivation are underlain by peat from 10 to 15 feet deep. Large areas of peat land in the Dismal Swamp district of Virginia and North Carolina are successfully devoted to the growth of potatoes, corn, wheat, and other crops. An average yield of more than 30 bushels of wheat per acre was obtained for several years on the well-tilled farm of the Wallace brothers, of Wallaceton, Va. Extensive use of peat soils for crop cultivation is also made in Minnesota, Wisconsin, Michigan, Iowa, Illinois, Indiana, and Ohio. Thousands of acres are already under cultivation, and millions more may be reclaimed by proper drainage and clearing. In fact, the economic future of entire counties in some of these States seems to be directly dependent upon the successful reclamation of peat bogs and swamps.

In Roseau, Marshall, Pennington, and Red Lake counties, Minn., where excellent crops of flax, barley, and oats are grown upon reclaimed areas, the peat is so shallow in many places that it may be penetrated by a deep tiller. Peat lands in the big tamarack and spruce swamps of northern Minnesota are being divided into homesteads with the design of draining and clearing them for agricultural use.

TREATMENT.

The prime requisite for the successful cultivation of peat land is a proper system of drainage. The water table must be kept far enough below the surface to protect the plants from excessive moisture, yet not so far that they will lack sufficient moisture. As pointed out by Alway,[8] the climate controls to a large extent the depth to which the water table must be lowered. It is hardly possible to lower the water level too far in regions of heavy rainfall, but it is possible in regions of scant or medium rainfall. To obtain the greatest crops in parts of the country that have a cool climate the water table should be kept from 20 to 40 inches below the surface. The drainage problem is an engineering one, and before any attempt is made to reclaim a peat swamp or bog levels should be carefully taken to ascertain whether cheap drainage is feasible.

The drainage of most bogs is comparatively simple, but peat-forming basins in which the peat is accumulating below a permanent water level can not generally be drained far below the surface of the peat except at great expense. However, many peat-forming basins in the region of the Great Lakes and in the New England

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Alway, F. J., Limitations on the cultivation of peat land in Minnesota: Am. Peat Jour., Apr., 1916, p. 65.

States, where most of the depressions in which peat has accumulated were formed by the Wisconsin or last glacial drift, may be drained by short drainage canals that connect the edge of the basin at the lowest level with an adjacent stream. Tile drains, though expensive to install, generally prove more satisfactory and ultimately more economical in reclaiming peat areas than open ditches, which must frequently be dredged.

Many peat bogs must be cleared and grubbed before they can be cultivated. The surface of the bogs may generally be prepared for cultivation with comparative ease, but swamps that are overgrown with trees can not be cleared and grubbed except at great expense. However, this expense is sometimes offset by the value of the timber obtained.

The method of tillage is largely regulated by the depth of the peat. Shallow peat may be tilled in the same manner as ordinary loam, but the great peat deposits of northern Minnesota, Wisconsin, and Michigan, which range in depth from 5 to 20 feet, must be tilled in a radically different way.

In peat areas where summer frosts occur the soil must be specially treated. Damage to crops may usually be avoided by spreading a layer of sand, clay, or loam 2 or 3 inches thick, over the surface, but this is expensive and for large areas is therefore impracticable. Grass, clover, and certain other forage crops that are immune from damage by summer frosts may be sown on peat areas without risk of loss, but as climatic conditions differ in different areas crop practices suitable to one area may be unsuited to another.

Many peat soils, especially deep peat deposits, must be fertilized before they can be used for growing crops successfully, for they do not contain certain minerals that are required by plants. Potash must be added to many peats, and phosphates and nitrates must be added to some, though most well-decomposed peat soils, after they have been thoroughly plowed and aerated, are rich in nitrogen. If a peat soil is to be used to raise alkaline-soil crops and its acidity can not be corrected by plowing and aeration, lime should be applied to it. If properly used, lime will increase the fertility of the soil. Sources of limestone from which lime may be made are noted on pages 82–91. The limestone should be ground or burned before it is used as fertilizer, for the lime is thus made available immediately, whereas if used unburned some varieties of limestone, notably shell "marl," are relatively inactive during the first growing season after their application to the soil. Lime releases potash from certain silicates; it promotes the decomposition of the peat, freeing soluble nitrogen; if applied to sour soil, it corrects the acidity; and if applied to peat soils that harden in lumps on drying, it makes them easy to work.

STOCK FEED.

Black humified peat is used both in Europe and in the United States for compounding stock feed. The peat is prepared in substantially the same way as for fertilizer. (See pp. 61–62.) After being air-dried and partly carbonized the peat is screened and reduced to a powder containing about 10 per cent of moisture. The powdered peat is then used as an absorbent for the uncrystallized residues obtained in refining beet and cane sugar, which, because of their viscidity, are otherwise not suitable for feeding stock. This valuable food may thus be economically fed to cattle and other live stock without causing gastric disorders. It is said that the peat also stimulates digestion, contributes proteid substance, and is an excellent substitute for charcoal. Charred dried peat is also used as an ingredient of food for poultry and other stock. In European countries peat mull prepared from moss and sedge peat is used as a base for stock feed.

ABSORBENT AND DISINFECTANT.

Fibrous peat may be profitably employed as stable litter, for when so used it absorbs nitrogenous liquids, which, though valuable for use in fertilizers, are ordinarily wasted. Moreover, it checks decomposition and absorbs gases, so that it should be an effective deodorizer and disinfectant. For this use it is superior to lime and ashes and some of the more expensive disinfectants, and it is a nearly ideal material for use in earth closets and other receptacles for moist waste organic matter. The best material for this purpose is found in the upper layer of deposits formed from sphagnum moss, an enormous quantity of which is available in the sphagnum bogs of the Great Lakes region and the New England States.

FUEL.

GENERAL FEATURES.

Because of its high content of carbon and because it will ignite and burn freely when dry, making a hot fire, peat is used as fuel in countries where the coal supply is below the normal requirements. In Europe between 15,000,000 and 20,000,000 tons of hand-cut and machine peat are consumed annually. Peat has been the only domestic fuel of the common people in Ireland from the traditional time when the country was deforested. The peat fire on the hearth, like the jaunting car, typifies Irish environment, and when the tourist seeks a memento of his visit to that country he usually selects some souvenir carved from the black oak that has lain for centuries protected by beds of peat from the attacks of fungi and bacteria. Peat

is cut by hand in blocks by the peasants for domestic use, and machine-cut peat is sold in blocks for both domestic and industrial use. (See Pl. IV, *B*.) Many attempts have been made both in Europe and in the United States to manufacture peat briquets for commercial use, but, though briquetted peat is more efficient than hand-cut or machine-cut peat, its manufacture has never advanced beyond the experimental stage on account of the high cost of production.

The peat in an undrained bog contains about 90 per cent of water, which must be reduced to 30 per cent before it can be used as fuel. By thoroughly draining the deposit about 10 per cent of the original water contained in the peat may be removed, but the remainder, which is largely held in the microscopic plant cells and minute intercellular spaces, can not be reduced below 70 per cent without drying in the open air or in a heated chamber. Artificial drying to remove all the excess moisture, however, requires the expenditure of so much heat in comparison with the heat obtainable from the fuel prepared by this method that it has not proved commercially feasible. Peat fuel should therefore be prepared during the air-drying season, which in the United States usually begins in April or May and ends in October. As Director Haanel[9] has so well put it: "The forces of nature, the sun and the wind, which cost nothing, should be used, and any improvement in this process will lie in the direction of labor-saving devices." It seems, however, that artificial drying might be economically employed by utilizing waste heat from blast furnaces or other sources.

PEAT FUEL IN THE UNITED STATES.

Although between 15,000,000 and 20,000,000 tons of peat fuel are produced and consumed annually in Europe in generating heat and power, only small quantities of peat fuel have been produced in the United States because of the abundance of coal, which is more efficient and in normal times can be cheaply prepared and more readily transported to the consumer. The interest shown in peat fuel and its possibilities in the United States has thus far been largely scientific and experimental, and the attempts that have been made here to produce it on a large scale have not been successful. The failure, however, appears to have been due not to a lack of market for the product but to the lack of sufficient capital, to the inexperience of operators, to the failure to recognize that peat is inferior to coal, and to preventable engineering errors. Operators say that air-dried machine peat can be produced in the United States at a cost ranging

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[9] Haanel, B., Peat as a source of fuel: Comm. Conservation, Canada, Ninth Ann. Rept., p. 16 (reprint), 1918.

from $1.50 to $5 a ton, the exact figure depending on the size and efficiency of the plant; and in some parts of the country it could perhaps successfully compete with other fuels for both domestic and industrial use. In many places where peat fuel has been used in this country it has proved very satisfactory and has found ready sale as fast as produced.

In recent years the increasing cost of producing coal has led to a general advance in price. This condition, aggravated by an appreciable reduction in the visible coal and oil supply and the rapid exhaustion of our forests, has strongly impressed upon economists and others the necessity of investigating other fuels and sources of power wherever they can be more economically used.

Van Hise,[10] in urging the conservation of our wood and coal reserves, said:

> So far as practicable other products should be substituted for wood. The original forests of the United States contained not less than 850,000,000 acres, having not less than 4,800,000,000,000 feet of merchantable saw timber. This was our magnificent original heritage. The United States as a Nation has existed a century and a quarter, and what have we now? In that brief time approximately one-half of the value of our forests has gone. * * *
>
> So far as practicable substitutes should be used for coal. Even if all possible economies and substitutes are introduced, the most sanguine can not hope that the supply of fuels will be sufficient to meet the needs of the people for more than a small fraction of the time we look forward to as the life of this Nation.

Although peat fuel may not be extensively produced in the United States in normal times as long as there is an abundant supply of coal, except possibly in localities where conditions are peculiarly favorable, it has great potential value as a source of heat and power and may be utilized to conserve our reserves of coal and wood and also, during economic and industrial crises, may be used locally in some States to prevent a shortage of fuel.

Many extravagant claims concerning the fuel value of peat have been made, but the sooner its inferiority to coal is recognized the better for the peat-fuel industry. Over a million dollars have been spent in this country in trying to produce some form of peat fuel equal to coal in heating value, and yet we have no commercial peat-fuel industry.

Careful consideration of all the factors leads to the conclusion that peat can be converted into fuel on a large scale in the United States only in the form of machine blocks, powder, and gas. Cut peat, however, is well adapted for home use by the owners of small de-

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[10] Van Hise, C. R., The conservation of natural resources in the United States, pp. 210, 256, 359, New York, Macmillan Co., 1910.

posits, but probably could not be marketed commercially. As complete descriptions of peat-fuel machinery and manufacturing processes may be found in United States Bureau of Mines Bulletin 16, only brief discussions of these phases of peat-fuel production are given here.

METHODS OF PREPARATION.

CUT PEAT.

Owners of small bogs who desire to prepare peat fuel for home use should adopt the handcut process, which is widely used in Ireland. Before this method can be employed the deposit must be thoroughly drained and cleared and the turf removed from its surface. Built-up bogs can usually be drained to the bottom by a simple system of surface ditches. Filled basins, however, can not generally be drained far below the surface of the peat without incurring great expense and are therefore not so well adapted to hand digging as built-up beds.

After the surface of the bog has been cleared the peat is dug in brick form with a special tool called a slane. (See Pl. IV, *B*.) This instrument, which can be made by a blacksmith, is a narrow spade with a sharp steel lug welded on one side at right angles to the edge of the blade.

The blocks of peat range from 8 to 10 inches in length, from 4 to 7 inches in width, and from 3 to 6 inches in thickness, their dimensions depending on the size of the slane. As soon as they are dug they should be removed to the drying grounds and stood on end or placed on covered racks. At the end of about four weeks, during which time they should be frequently turned, their moisture content will usually be reduced to about 30 per cent, and the blocks will then be ready for storage. As cut peat absorbs water rapidly, great care should always be taken to protect the dry blocks from rainfall. Peat fuel prepared in this way is bulky, easily crushed, and burns rapidly with considerable waste. In heating value it is superior to wood, but it is unfit for commercial use.

MACHINE PEAT.

If it is desired to produce peat fuel of better quality and in larger quantities than is possible by hand, the machine method should be adopted. This process, so far as the writer knows, is the only one that has proved commercially successful in Europe. The machinery for a small plant is simple and easily operated. It consists essentially of an excavator and a macerator. The purpose of the macerator is to grind the constituents of the wet peat into a homogeneous pasty

mass, which may be shaped into compact blocks. In principle and form the latest types of peat machines are similar to the pug mill or grinding machine for plastic clay. Many of the experimental plants in the United States have used brickmaker's pug mills very slightly changed to grind peat and have found them well suited for the purpose. After being thoroughly macerated the peat is shaped into compact blocks as it comes from the machine or is spread in a layer from 8 to 12 inches thick on the drying grounds, and the bricks are marked off by hand as the spreading proceeds. When partly dry the bricks are loosely stacked or placed on drying racks and thereafter handled in the same manner as cut peat.

A specially designed and constructed machine is used for the commercial production of peat fuel. This machine consists of a receiving hopper attached to a vertical or horizontal cast-iron body, in which revolve one or two knife-armed shafts. These shafts are also provided with spirally arranged flanges for moving the peat to the grinding knives and advancing it to the device for cutting the peat pulp into bricks of uniform length as it issues from the orifice of the machine. The principal types of peat machines of modern construction are fully described and illustrated in a publication of the Canada Department of Mines.[11]

Machine peat which is allowed to dry slowly contracts into a dense mass covered by a gelatinous, skinlike substance called hydrocellulose. After the moisture has been reduced to about 25 per cent this coating renders the machine peat impervious to water, even when immersed. It is clean to handle and burns freely, yielding an intense heat and producing no soot or other objectionable deposit. For open grates, this fuel is nearly ideal, and it is said that peat may be burned in the same stoves as coal and wood. However, the best results for household use could probably be obtained by burning it in a stove with relatively small grate openings and a restricted draft.

The following data,[12] which are based upon the early experiments of the Canada Department of Mines, show the cost of a machine-peat fuel plant and of producing air-dried machine peat in commercial quantity in Canada in 1914. The cost of production was calculated from an output in five months of 3,300 short tons of fuel containing 25 per cent moisture.

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[11] Nystrom, Erik, Peat and lignite; their manufacture and uses in Europe: Canada Dept. Mines, Mines Branch, 1908.

[12] Haanel, B. F., Peat, lignite, and coal: Canada Dept. Mines, Mines Branch, Pub. 299, p. 27, 1914.

Cost of a 30-ton Anrep peat plant and deposit.

100 acres of peat land at $6 an acre	$600
Peat machine, locomobile, tracks, cars, cables, etc	7,500
Blacksmith shop, office, loading platform, and railway siding	1,100
Drainage, clearing, etc	1,500
	10,700

Cost of producing a ton of air-dried machine peat.

Labor and supervision	$1.21
Repairs, fuel, oil, waste, etc	.15
Amortization and interest	.34
	1.70

Another experiment is now in progress in Canada, and it is understood that the cost of production is lower than that shown by these figures.

POWDERED PEAT.

For certain commercial uses powdered peat has many advantages over machine peat. The cheapest way to prepare it is by the air-drying process, by which the moisture may be reduced in the field. If raw peat is allowed to lie in heaps until natural drainage and evaporation have reduced the moisture content to about 50 per cent, it may be prepared for use under steam boilers by driving off about half the remaining moisture with waste heat from flues or other sources and pulverizing the resulting material. The powdered peat may then be blown with compressed air into the furnace, where, by means of forced draft, ignition is almost instantaneous, and instead of burning on the grate the peat forms a gas which gives a uniform fire throughout the combustion chamber. Good peat thus treated, when burned in furnaces designed to give the most complete and efficient combustion, will generate nearly as much energy in the form of live steam as the same weight of powdered coal. According to reports in this country powdered peat has great possibilities, not only for boiler firing but for metallurgical work and for use in cement and other kinds of kilns in which powdered coal has been successfully burned.

PEAT BRIQUETS.

Peat briquets are usually made from peat which has been air dried to a moisture content of 40 per cent. After the peat has been macerated and powdered, the moisture is further reduced to about 15 per cent by artificial drying. A binder is then mixed with the peat, and the mixture is compressed into cylindrical or prismatic shape by means

of a piston subjected to a pressure of 18,000 to 30,000 pounds per square inch.

Although there is little more heating value per pound in peat briquets than in machine peat, the briquets are cleaner, more compact, greater in heating value per volume, and generally more attractive than machine peat. These advantages, however, are more than offset by the high cost of production.

Artificial drying requires so much heat in comparison with that obtainable from peat briquets prepared in this manner, and the cost of binders and compressing is so great that the process is at present of doubtful commercial value in the United States.

PEAT COKE AND CHARCOAL.

Peat charcoal was made in Europe for hundreds of years by piling cut peat in dome-shaped heaps, covering it with soil, and burning the peat with a restricted supply of oxygen. This process is little used now, and peat charcoal has been displaced by peat coke, which is manufactured in Europe by the Ziegler process. According to this method the coke is produced by heating machine peat blocks in specially designed retorts. Good peat coke is equal in quality to the best grades of charcoal produced from wood. If made from blocks of well-macerated, thoroughly decomposed peat that contains little ash, peat coke is compact and hard and should be able to compete with coke manufactured from coal. Alcohol, acetic acid, ammonia, ammonium sulphate, paraffin wax, illuminating and lubricating oil, phenol, and asphalt are some of the valuable by-products that may be obtained in coking peat by the dry distillation process.

Peat coke is extensively used in Europe, but in the United States, though it could probably be prepared for about $4 a ton, this material has never been commercially produced. There are large deposits of peat suitable for the production of coke within a few miles of the iron-mining districts of Minnesota, and it seems that the practicability of locating peat-coke plants in this region should receive thoughtful consideration from engineers.

PRODUCER GAS AND BY-PRODUCTS.

There are two kinds of by-product gas-producing plants that use peat—the Mond and the Frank-Caro. The same principle is applied in both, and the differences between them are minor. Crushed peat is fed into a furnace in which combustion is regulated by steam and hot air. The peat burns at the bottom of the feed shaft and reacts upon the steam, forming water gas and ammonia. These gases are next cleansed of tar by means of a scrubber and are subjected to a fine shower of sulphuric acid, which converts the ammonia into am-

monium sulphate and purifies the water gas. After being cooled the water gas may be used under steam boilers, in internal-combustion engines, and for other purposes.

Peat containing 2.5 per cent of combined nitrogen, when treated by the Mond process, at Cordigoro, Italy, is said to have yielded 170 pounds of ammonium sulphate to the ton. Gas-producing plants using peat fuel have been operated in England, Ireland, Germany, Sweden, Italy, and Russia, but not in the United States, although experiments have been made here. Analyses of the peats of the United States show that they are rich in combined nitrogen, from 70 to 85 per cent of which—a proportion that in some peats amounts to more than 2 per cent of their dry weight—could be recovered in the form of ammonium sulphate in by-product gas-producing plants.

PEAT AND PEAT MOSS AS ANTISEPTICS AND MEDICAMENTS.

ANTISEPTIC DRESSING.

Large quantities of peat or sphagnum moss have been produced and utilized in this country for surgical dressings. According to J. W. Hotson,[13] under whose direction peat moss was collected in the Northwestern States for surgical use, 595,540 peat-moss pads were prepared from October, 1917, to November 11, 1918, by the northwestern and Atlantic divisions of the American Red Cross. Most of the moss was gathered by volunteer labor from the bogs of Washington, Oregon, and Maine, and the pads were used in military hospitals both at home and abroad. At first the surgeons of the United States Army were not disposed to use the pads, but later the value of sphagnum was universally recognized. The gathering of moss and preparing of pads was largely curtailed when the armistice was signed, but it seems that the value of peat moss as an absorbent and disinfectant demonstrated during the war will not be forgotten, and that it should be able to compete commercially with cotton for these purposes in normal times. A brief discussion of the best kinds of peat moss and of the method of gathering it is given in the report by Hotson.[13]

MUD BATHS.

At certain health resorts in Germany and Austria peat has long been successfully used for so-called mud baths, and during recent years experiments have been made to test the healing properties of peat in some of the sanitariums of this country. Well-decomposed peat, free from coarse or woody material, is the basis of the mixtures used, and it is reported that persons suffering from rheumatism and like diseases are materially benefited by the treatment.

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[13] Hotson, J. W., Sphagnum from bog to bandages: Washington Univ. Puget Sound Biol. Sta. Pub., vol. 2, No. 47, pp. 213, 243, 1919.

OTHER USES.

PACKING MATERIAL.

Because of its lightness, resiliency, and antiseptic properties, peat makes excellent packing material and has long been used for packing eggs, fruit, vegetables, and fragile articles. Dry peat is a nonconductor of heat, and hence is valuable in ice houses and as a packing for water pipes. The best material is obtained from the fibrous types of peat, consisting of partly disintegrated grasses and mosses. Peat moss is also utilized in shipping flowers, shrubs, and plants.

PAPER, WOOD, AND CLOTH.

Peat was used a few years ago at a plant near Capac, Mich., for the manufacture of cardboard and paper. Grass and sedge peat would probably make the best paper stock, as this peat consists of strong fibrous material. Rugs are also made in this country from so-called wire grass (*Carex stricta*) grown upon peat. Peat is successfully used in Europe for the manufacture of wall board and other artificial wood products. German and Swedish manufacturers have also made a durable yarn from a mixture of peat moss, shoddy, and wool, from which a cloth resembling cheviot is woven.

THE PEAT INDUSTRY IN THE UNITED STATES.

PRODUCTION.

The following tables show the production, prices, and value of the peat marketed in the United States in recent years:

Peat produced in the United States, 1916–1921.

Year.	Number of plants reporting.	Quantity (short tons).	Value.	Average price per ton.
1916	13	52,506	$369,104	$7.03
1917	18	97,363	709,900	7.29
1918	25	107,261	1,047,243	9.76
1919	15	69,197	705,532	10.20
1920	18	73,204	921,732	12.59
1921	21	30,406	260,119	8.55

Peat used in manufacturing fertilizer in the United States, 1916–1921.

Year.	Quantity (short tons).	Value.	Average price per ton.
1916	48,106	$336,004	$6.98
1917	92,263	658,500	7.14
1918	79,573	775,313	9.74
1919	54,690	557,240	10.19
1920	63,272	773,685	12.23
1921	29,460	251,046	8.52

Peat used in manufacturing stock feed in the United States, 1916–1921.

Year.	Quantity (short tons).	Value.	Average price per ton.
916	4,300	$32,250	$7.50
917	5,100	51,400	10.08
918	7,096	106,935	15.07
919	6,402	98,940	15.45
920	[a] 9,102	[a] 143,047	15.58
921	[b] 946	[b] 9,073	9.59

[a] Includes small quantity of moss and stable litter.
[b] Includes small quantity of fuel, moss, and stable litter.

IMPORTS AND EXPORTS.

The imports of peat in 1920 consisted of peat moss or litter, which is used largely for packing material. The quantity was 2,762 tons, or six times as much as in 1919. The price per ton, however, fell from $35 to $13. The imports in 1921 amounted to 3,450 tons, but the price per ton fell to $6.60. No exports of crude or peat products were reported in 1920 or 1921.

SUMMARY.

Peat and peat moss used in the manufacture of peat products in the United States in 1920 and 1921.

Kind of product.	Production.		Imports.		Consumption.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
1920.						
Fertilizer and fertilizer ingredient	63,272	$773,635			63,272	$773,635
Stock feed	[a] 9,182	[a] 143,047			9,182	143,047
Fuel	750	5,050			750	5,050
Moss	([b])	([b])	2,762	$36,201	2,762	36,201
	73,204	921,732	2,762	36,201	75,966	957,933
1921.						
Fertilizer and fertilizer ingredient	29,460	251,046			29,460	251,046
Stock feed	[c] 946	[c] 9,073			[c] 946	[c] 9,073
Fuel and miscellaneous products	([c])	([c])			([c])	([c])
Moss	([c])	([c])	3,450	22,754	[c] 3,450	[c] 22,754
	30,406	260,119	3,450	22,754	33,856	282,873

[a] Includes small quantity of moss and stable litter.
[b] Included with stock feed.
[c] Inludes small quantity of fuel, moss, and stable litter.

CONSUMPTION.

The consumption of peat and peat moss (production plus imports) was 69,661 tons, valued at $721,877, in 1919; 75,966 tons, valued at $957,933, in 1920; and 33,856 tons, valued at $282,873, in 1921.

DISTRIBUTION OF PEAT PLANTS.

The 21 plants reporting production in 1921 were distributed as follows: New Jersey 4, New York 4, California 3, Illinois 2, and

Florida, Georgia, Massachusetts, Michigan, Minnesota, New Hampshire, North Carolina, and Wisconsin 1 each. California was the largest producer, with an output of 12,672 short tons, valued at $117,580. New Jersey was second in rank, with an output of 12,051 tons, valued at $94,269; and Illinois was third, but the State total can not be published without revealing confidential information, as there were only two producers.

PRODUCERS OF PEAT IN THE UNITED STATES.

The following individuals and companies reported to the Geological Survey that they produced crude peat or peat products in the United States in 1921:

Alphano Humus Co., Whitehall Building, New York, N. Y.
Appleton Peat Products Co., Appleton, Wis.
Blaine, J. H., Hopewell Junction, N. Y.
Chapman, I. S., & Co. (Inc.), 937 Third Street, San Bernardino, Calif.
Craig, William H., Fishkill, N. Y.
Day, James H., 35 South Street, Milford, N. H.
Hennepin Atomized Fuel Co., 406 Tribune Annex, Minneapolis, Minn.
Humus Natural Manure Co., 1964 Broadway, New York, N. Y.
Hyper-Humus Co., Newton, N. J.
International Products Co., 132 Boylston Street, Boston, Mass.
McElhone, Asa, Fishkill, N. Y.
Manito Chemical Co., Peoria, Ill.
Marcrum, J. G., Netcong, N. J.
National Humus & Chemical Co., Chassell, Mich.
Pacific Humus Co., 205 Central Building, Pasadena, Calif.
Phos-Pho Germ Manufacturing Corporation, New Bern, N. C.
Ranson, Robert, St. Augustine, Fla.
Riverside Orange Co. (Ltd.), Arlington Heights, Riverside, Calif.
Sims, Alfred F., Sag Harbor, N. Y.
Southern Humus Co., Smyrna, Ga.
Wiedmer Chemical Co., Pierce Building, St. Louis, Mo.

COMMERCIAL FACTORS.

CAUSES OF FAILURE.

Although some of the elements of successful peat production have been mentioned, full descriptions of the factors that control the profitable utilization of a peat deposit are here given in order to show the causes of past failures. Some of the attempts made in this country to produce peat on a commercial scale have not been successful, but many of the failures appear to have been due not to a lack of market for the product but to the lack of sufficient capital, to the inexperience of operators, and to the injudicious choice of deposits, plant sites, manufacturing processes, and machinery. All these factors should be carefully considered by prospective producers.

LOCATION.

The location of the deposit is the prime factor in the successful operation of a peat plant. Many deposits containing peat suitable

for commercial use are known in all the peat areas, but under present conditions in the United States only deposits located near the markets and where cheap labor and transportation may be obtained can be profitably developed. Thus the conditions for successfully producing peat fuel are most favorable in Minnesota, Wisconsin, Michigan, and the New England States, which contain but little coal and because of their cold climate and extensive manufacturing industries consume large quantities of fuel. In the Southern Atlantic States, although the climate is mild and the demand for fuel relatively light compared with that in the Northern States, peat is the only local mineral fuel available. (See Pl. I.)

Fertilizer plants should, of course, be preferably located near the agricultural districts and the commercial fertilizer plants, notably in New York, New Jersey, Illinois, and Virginia. As peat fertilizer is not well known in this country a market will have to be created in many places, but if high-grade products can be sold at a low price this should not be difficult.

QUANTITY AND QUALITY.

The prospective deposit should be carefully surveyed to insure that it contains a sufficient quantity of good peat before plans are made for the erection of a plant. Typical samples should be analyzed to ascertain whether the peat is of suitable quality for the purpose desired. One of the great handicaps suffered by the peat industry has been the lack of uniformly good quality, and as the success of a plant depends upon the kind of peat used due care should be observed in its selection.

SIZE OF DEPOSIT.

The size of the deposit to be selected depends upon the capacity of the machinery to be used, but it is generally unwise to erect a plant on a deposit less than 100 acres in area and 4 feet in depth. The average peat deposit will yield approximately 200 tons of air-dried peat per acre-foot. The quantity of peat in a given deposit may therefore be approximately determined by multiplying the area in acres by the depth in feet and the product by 200. The topographic maps issued by the United States Geological Survey show many valuable peat deposits as swamps, the area of which may be readily estimated. The dimensions of deposits that have not been mapped should be carefully measured.

Although peat deposits less than 4 feet deep may be advantageously used for the growth of crops, they are of little value as a source of fertilizer, fuel, or other commercial peat products. Numerous tests of depth should therefore be made and the average thickness of the

peat determined. An earth auger may be employed for this purpose, but a sampling tool especially designed by the late Prof. Davis[15] for testing the depth of peat deposits was used in field work for this report and is superior to the earth auger for sampling peat.

SELECTION OF SAMPLES.

Samples of peat should typify the entire deposit from which they are taken or a definite portion of it. Specimens consisting of material taken at depth intervals of 1 foot and at areal intervals of 100 yards in a small, shallow deposit usually represent the general composition of the deposit. It is obviously impossible to obtain a typical sample of the peat in a large, deep deposit. Such a deposit should be divided into blocks and typical samples taken from each block. Tests are generally made at depth intervals of 2 feet and areal intervals of one-fourth of a mile in large deposits. The material taken from each block may later be mixed in order to obtain a representative specimen. Structural features should be noted as deposits are sampled, and if the peat is distinctly bedded samples should be taken from each bed and separately analyzed. If the lower strata contain a large proportion of inorganic impurities the fact should be noted in order that these strata may be avoided in excavation.

As analyses of dry peat show its chemical composition and value for fertilizer and fuel as well as analyses of wet peat, it is unnecessary to place samples taken for analysis in air-tight containers. For a simple test about 10 pounds of raw peat and for a detailed chemical analysis about 40 pounds are required. Samples should ordinarily be air-dried to a moisture content of about 50 per cent in the field and sent to the laboratory in canvas bags. However, if it is desired to identify the plant remains, small specimens should be placed in sealed bottles or air-tight soil cans, so that the peat may later be examined under the microscope in its native condition.

SIMPLE TESTS.

Black, thoroughly decomposed friable peat from a deposit that has been well drained, aerated, and successfully cultivated for several seasons, is usually suitable for an ingredient of commercial fertilizers or, when limed and inoculated with nitrifying organisms or composted with manure, for a direct fertilizer.

Some evidence of the fuel value of peat may be obtained from a small sample that has been macerated in the hands, pressed into a cake, and allowed to dry in the sun. If it is easily disintegrated and

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[15] Davis, C. A., The uses of peat for fuel and other purposes: Bur. Mines Bull. 16, p. 71, 1911.

plastic while wet, it may be readily worked in a peat machine, and if when dry the cake is dense, tough, and hard, the peat will probably make good fuel unless the ash content is too high. However, if the dry peat cake is soft, fibrous, and easily crushed, the peat is not well adapted to the manufacture of fuel.

The heating value and ash content of prospective peat fuel for home consumption may be determined by a simple practical test. A typical sample should be taken from the bog, thoroughly macerated, dried, and weighed. If when burned in an ordinary heating stove the heat generated is almost equal to that produced by ordinary bituminous coal, and if after complete combustion the weight of the accumulated ash does not exceed 20 per cent of the weight of the dry peat put into the stove, its usefulness as domestic fuel is established.

PREPARATION OF SURFACE.

The surface of peat deposits must be prepared by draining and clearing before the peat can be removed. As these factors have already been discussed, only a brief summary is here given. The water level should be reduced by a system of tile drains or ditches to a point between 3 and 5 feet below the surface. Only deposits that can be cheaply drained should be selected. Bogs are usually easy to drain, but the drainage of some peat-forming basins is so difficult that their surfaces can not be economically prepared for peat production by known methods. Marsh deposits and bogs are cleared by removing the living grasses and mosses and grubbing out the shrubbery. The clearing of swamps overgrown by mature trees is expensive, but this expense is sometimes offset by the value of the timber obtained.

PROCESSES AND MACHINERY.

The failure of many peat plants in the United States has been due to improper choice of manufacturing processes and machinery. The excess moisture in the peat must be eliminated at as early a stage as possible in the manufacturing process. This drying can be most economically done by evaporation on the surface of the deposit. Whether for the manufacture of fertilizer or fuel, machinery of proved efficiency must be selected. Field equipment propelled by caterpillar drives seems to be well suited for use on boggy surfaces. The most successful peat-fuel machinery that has been used in North America was designed by the Canada department of mines and operated at Alfred, Ontario. John N. Hoff, of New York City, has successfully operated peat-fertilizer machinery for several years on a deposit near Great Meadows, N. J. Though experimental work is always commendable if it is properly limited, the methods and

machinery that are successful elsewhere in North America and in the peat-producing countries of Europe should be used. The peat industry of European countries is well developed, and detailed information concerning European peat machines is available in Bureau of Mines Bulletin 16 and in the report by Nystrom, published by the Canada Department of Mines.[16]

MARKETS.

The principal markets for fertilizer peat are in or near the great agricultural States, notably New York, New Jersey, Illinois, Virginia, Kentucky, Tennessee, and Florida, and the largest buyers are the manufacturers of commercial fertilizer, brokers in fertilizing materials, florists, and farmers. Markets could probably be created in many other agricultural States. Stock-feed peat is sold to manufacturers of stock feed and to live-stock growers. Practically all the peat deposits in this country occur in regions remote from coal fields, and it seems that markets for peat fuel might therefore be created in some of the States where peat is abundant.

AREAS OF SPHAGNUM MOSS.

Sphagnum moss grows in low, undrained regions where the humidity of the air is high and the temperature low and where other conditions of growth are favorable. These conditions are found in the extreme northwestern and northeastern parts of the United States, as well as in the northern part of the Great Lakes States.

Northwestern States.—The largest areas of high-grade sphagnum moss in this country are in Washington and Oregon. It is estimated that there are 25,000 acres of bog land in the western part of Washington alone, much of which is overgrown by sphagnum moss suitable for surgical dressings and packing material. Some of this moss grows in climbing bogs, and in a few of these bogs the center is higher than the margin, a condition especially favorable for the growth of surgical sphagnum.

Northeastern States.—According to G. E. Nichols,[17] the bogs of Maine contain more sphagnum than those of any other State in the North Atlantic region, but relatively large sphagnum bogs also occur in some of the other Northeastern States. Sphagnum moss suitable for surgical dressings, as well as for other purposes, grows in the following localities:

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[16] Nystrom, Erik, Peat and lignite, their manufacture and uses in Europe: Canada Dept. of Mines, Mines Branch, 247 pp., 33 pls., 1908.

[17] Nichols, G. E., written communications, 1918.

- **Maine:**
  - **Aroostook County:** Otter Pond.
  - **Penobscot County:** Alton Bogs.
  - **Waldo County:** Cross Pond.
  - **Washington County:** Lake Hadley, Lake Meddybemps.
- **New Hampshire:**
  - **Cheshire County:** Bog near East Jaffrey.
  - **Hillsborough County:** Bogs near Greenfield, South Milford, and Ponemah.
  - **Rockingham County:** Bog near Fremont.
- **Vermont:**
  - **Addison County:** Bristol Pond, East Monkton Bog, Monkton Bogs.
  - **Grand Isle County:** Isle La Motte Bog.
  - **Franklin County:** Cranberry "Marsh."
- **Massachusetts:**
  - **Middlesex County:** Littleton Bog, Tophet "Swamp," West Bedford Marsh.
  - **Norfolk County:** Norwood Bog, Walpole Bog.

Many other areas in the Northeastern States are overgrown by sphagnum, but most of it is not suitable for surgical dressings. However, it could be advantageously used for packing material and stable litter. Further references to areas in the New England States that contain sphagnum are made in the discussions of the localities tested for peat.

Other States.—Although large areas of sphagnum are found in the Great Lakes States, varieties suitable for surgical dressings are not abundant because of the excessive heat in summer and the extreme frost in winter. The largest sphagnum bogs in this region occur in Beltrami, Itasca, Koochiching, and St. Louis counties, Minn.; in the northern counties of Wisconsin, Michigan, and Indiana; in northern and western New York; in Portage County, Ohio; and in Pennsylvania. Immense quantities of moss that might be used for packing material, paper stock, and stable litter could be obtained from these bogs. In New York surgical sphagnum grows in the bogs of the Adirondack region in the northern part of the State; in the Cicero Swamp, north of Syracuse; at Mud Pond, near Fairville; and in the western part of the State. Small quantities of surgical sphagnum grow in a few bogs in Pennsylvania, but according to Jennings *Sphagnum papillosum*, one of the best species, does not occur there. The Pymatuning Swamp near Hartstown, Lost Pond, Long Pond, and Half Moon Lake contain sphagnum, but it is not well adapted for surgical use. The best species probably occur in the highlands of the north-central and western parts of the State. A list of the areas in western Pennsylvania that contain sphagnum may be found in a report by Jennings.[18] Areas covering many square miles in Camden County, N. C., are said to contain *Sphagnum cymbifolium*, one of the highest grades of peat moss.

Further data showing the specific location of sphagnum in the different States are given in the discussions of localities where the

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[18] Jennings, O. E., A manual of the mosses of western Pennsylvania, Pittsburgh, Pa., 1913.

peat was sampled. The large quantity of sphagnum peat in the domestic deposits shows that sphagnum moss grew more extensively in this country in former times than it does now. It seems that when many sphagnum bogs matured and uncongenial trees and other plants appeared the sphagnum could not survive and that it died out in other bogs when the tamarack was cut.

MARL AND OTHER LIMESTONE DEPOSITS ASSOCIATED WITH BEDS OF PEAT.

GENERAL CONDITIONS.

Many peat deposits in the northern or glacial region are underlain by beds of marl, a white or gray claylike variety of limestone composed largely of calcium carbonate ($CaCO_3$), which was brought into lakes and marshes by springs or stream waters and precipitated through the agency of blue-green algae and stoneworts (*Chara*). These plants extract carbon dioxide from the water and thus cause the deposition of the lime held in solution. Deposits of fresh-water marl are common in Wisconsin, in the southern peninsula of Michigan, in northern Indiana, Illinois, and Ohio, in western New York, and in northwestern Pennsylvania. Shell limestone deposited by organisms is another kind of calcareous material which commonly occurs beneath peat in the coastal region. Dense fine-grained limestone, marble, travertine, oolitic limestone, and chalk, though not generally associated stratigraphically with peat, commonly occur in regions near peat deposits. On account of its acidity much peat land is of little value for general farming when first cleared, but it could be economically treated with lime from associated or near-by deposits and made to yield large alkaline or neutral-soil crops. Brief reference to the treatment of limestone for agricultural use and to the effect of lime on peat soils is made on page 65. Data concerning beds of both fresh-water and marine marl that occur in association with peat are given in conjunction with the discussions of peat localities on pages 91–202.

The following extract from a paper by Burchard and Emley[19] shows the age and general location of the principal limestone formations in the States that contain the most valuable peat deposits.

DISTRIBUTION OF LIMESTONE BY STATES.

NEW ENGLAND STATES.

Practically all the limestone in the New England States is so highly crystalline as to be considered marble. The principal areas

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[19] Burchard, E. F., and Emley, W. E., The source, manufacture, and use of lime: U. S. Geol. Survey Mineral Resources, 1913, pt. 2, pp. 1530–1546, 1914.

of calcareous rocks are near the coast of Maine, in Knox and Waldo counties, and in western Vermont, Massachusetts, and Connecticut. Lime is the principal product of the area in Knox County, Maine, and it is made also in Berkshire County, Mass., and in Litchfield and Fairfield counties, Conn. In Vermont also the marble is suitable for the manufacture of lime, although the production of lime in that State falls below that of the other States mentioned.

NEW YORK, NEW JERSEY, AND PENNSYLVANIA.

New York and Pennsylvania are both especially rich in limestone. A belt of Silurian limestones extends eastward from Buffalo nearly across New York, and adjoining this belt on the south are Devonian formations, which also carry limestones. On account of the proximity of these limestone areas to several east-west railroads and of the exceptional purity of the stone, they are extensively quarried, especially for flux for blast furnaces at Buffalo. East of Lake Ontario, in addition to a lobe of Silurian limestone there is an area of Ordovician rock which contains limestone in the vicinity of Watertown. Along St. Lawrence River and the northern end of Lake Champlain, Cambrian and Lower Ordovician limestones occur, and quarries are operated in the vicinity of Ogdensburg and Plattsburg. Lime is burned at many of these localities in New York, but the lime industry is much more widely distributed in Pennsylvania than in New York. In Pennsylvania limestones of commercial value occur in the western half of the State in the Carboniferous areas, and chiefly in the Pennsylvanian ("Coal Measures") formations. From the middle of the State eastward the limestones are chiefly of late Cambrian, Ordovician, Silurian, and Devonian ages, and the limestone areas are distributed in long, narrow strips, analogous to the outcrops of the "valley" limestones in the southern Appalachians. The dips of the beds in eastern Pennsylvania are steep as compared with those in the western half of the State.

Many of the limekilns in Pennsylvania are small and are operated intermittently by the farmers to furnish lime for local fertilizers.

Much of the limestone of New York, especially in the western half of the State, is high in calcium carbonate; in Pennsylvania both high-calcium and high-magnesian stone occurs in abundance, the magnesian rock being especially well represented in the valleys of southeastern Pennsylvania. The "cement" rock and purer limestone beds of the Lehigh district in eastern Pennsylvania are quarried to some extent for crushed stone. Near Philadelphia the limestone has been subjected to intense folding and pressure, and in many places the beds have been recrystallized to marble, although they are utilized mostly for lime rather than for marble. In northwest New

Jersey the beds utilized for crushed stone in the Lehigh district of Pennsylvania extend into Warren, Sussex, and Hunterdon counties, N. J. Much of this rock is highly magnesian.

The New Jersey stone area is limited to the northwestern and northern parts of the State, for the deposits of the Coastal Plain, which underlie the remainder of the State, consist mainly of feebly consolidated materials, such as clay and sand.

MARYLAND, DELAWARE, VIRGINIA, WEST VIRGINIA, NORTH CAROLINA, AND SOUTH CAROLINA.

The limestones of this area fall physically into three groups: (1) The nonmetamorphosed limestones of the Appalachian valleys; (2) the metamorphosed or crystalline limestones of the Piedmont region, both of which are hard limestones; and (3) the soft limestone of the Coastal Plain. The great limestone deposits of the valley of Virginia are the most noteworthy in this area. They are easily accessible and consequently are extensively utilized for lime burning. These same limestone belts extend from northern Virginia across the corner of West Virginia and through Maryland into Pennsylvania and Delaware. West of the Alleghenies there are deposits in eastern West Virginia, but only in the northern part of the State are they extensively utilized for the production of stone and lime. Southwestward they extend into Tennessee. Limestone is not abundant in the Piedmont region, except where it has been altered to marble, but it is quarried in a few places, notably in Henderson, Transylvania, and Yadkin counties, N. C.; Cherokee County, S. C.; Loudoun County, Va.; and Frederick and Carroll counties, Md. The hard limestones may be either high-calcium or magnesian rocks. The soft limestones of the Coastal Plain consist largely of shell marl, and important quarries are situated in Norfolk County, Va.; Craven and Jones counties, N. C.; and Charleston County, S. C. The shell limestones are generally quite pure and contain little magnesia, but they contain considerable silica in places, owing to the admixture of sand.

TENNESSEE, MISSISSIPPI, ALABAMA, GEORGIA, AND FLORIDA.

Calcareous rocks predominate, at least so far as suitability for quarrying is concerned, in Tennessee, northern Alabama, and northern Georgia, and much of the limestone is suitable for the manufacture of lime. In Franklin County, Ala., there are extensive quarries in an oolitic limestone that strongly resembles the famous Bedford (Ind.) limestone, and is of about the same geologic age. Much of the limestone quarried in these States is crushed for concrete, railroad ballast, wagon roads, and for fluxing iron ores. Some

hard limestone occurs in Tishomingo County, Miss., but owing to the proximity of large quarries in Alabama it has not yet been utilized to an appreciable extent. In the deposits of the Coastal Plain there are soft limestones of Cretaceous and Tertiary age. In Choctaw, Clarke, and Washington counties, Ala., these rocks are utilized. Florida is largely underlain by beds of shell marl and chalky limestone of Tertiary and Recent age, but these limestones are covered, for the most part, by comparatively thick deposits of sand and gravel. The Coastal Plain material that is utilized in this State for limestone and lime is mainly in the vicinity of Ocala.

WISCONSIN AND MICHIGAN.

A considerable part of the area of Wisconsin and Michigan is thickly covered by glacial deposits of clay, gravel, and sand. Doubtless this cover retards the development of quarries to some extent, first by obscuring outcrops of good limestone and second by the expense which its removal entails in quarry operations. Silurian rocks underlie the greater part of the eastern tier of countis in Wisconsin and contain a thick formation of magnesian limestone. This rock is quarried in many places for stone to be burned into lime and also to be crushed for concrete, macadam, and railroad ballast. The proximity of some of the quarries in eastern Wisconsin to water transportation on Lake Michigan has greatly aided their rapid development. The Silurian rocks on the west and extending across the southern tier of counties are bordered by a belt of rocks of Middle and Upper Ordovician age, which also contain magnesian limestone. The limestone quarries west of Green Bay and west and south of Lake Winnebago, as well as those in the southern counties, are in these rocks. Between the border of the Middle Ordovician area and the crystalline area of north-central Wisconsin is a wide belt of rocks of late Cambrian and early Ordovician age, consisting chiefly of alternating beds of sandstone and magnesian limestone. There are a few limestone quarries in these rocks, mainly near Mississippi River between Prairie du Chien and Hudson. The greater part of the lime made in Wisconsin is burned from Silurian magnesian limestone in the eastern part of the State, but there are a few small kilns burning lime for local use in the southern and western areas. One thin formation of relatively high calcium Ordovician limestone is burned for lime in Lafayette County.

In Michigan Devonian formations, consisting largely of limestone, border the northern part of the southern peninsula of the State along Lakes Michigan and Huron and also cross the southeastern part of the State from Lake St. Clair to the Ohio line. A small area of Silurian limestone borders Lake Erie in the extreme southeast corner

of the State, and at the extreme northern point of the southern peninsula there is also a narrow strip of Silurian rocks. Bordering the north end of Lake Michigan and the Strait of Mackinac are Silurian formations that constitute the country rock for some distance back from the shore in the northern peninsula. This is an extension of the belt of rocks that borders Lake Michigan in eastern Wisconsin. Adjoining the Silurian area on the west and north are rocks of Middle and Upper Ordovician age that enter the State from west of Green Bay, Wis., and succeeding these rocks toward the west and north are formations of late Cambrian and Ordovician age that form the shore line of Lake Superior east of Marquette and part of the shore line between Marquette and Keweenaw Point, but which contain little limestone of importance. The central area of the southern peninsula of Michigan is underlain by rocks of Carboniferous age, largely sandstone and shale. The limestone quarries in Michigan are therefore distributed mainly around the borders of the southern peninsula and near the shores of Green Bay and Lake Michigan in the northern peninsula, and are mainly in rocks of Ordovician, Silurian, and Devonian age. There are certain exceptions, however, such as the quarries near Saginaw Bay, which are in Mississippian limestone. The limestones of the Carboniferous and of the Devonian are generally high-calcium rocks; the lower limestones are generally high in magnesium.

ILLINOIS, INDIANA, OHIO, AND KENTUCKY.

The central part of Illinois is so heavily drift laden that quarries can not generally be opened economically, and this condition applies also to much of the area of northern and central Indiana and to parts of Ohio.

In this group of States the principal limestone formations are of Ordovician, Silurian, Devonian, and Carboniferous age. Of the Carboniferous rocks the lowest or Mississippian series contains the most important limestone formations in the western part of the area. In Illinois the Ordovician formations in the north-central part, the Silurian in the Chicago area, and the Silurian and Devonian in the northwestern part of the State are all worked for limestone. Some high-calcium limestone is found in the Ordovician, but the beds are mainly magnesian. The Silurian limestones are also magnesian, but the Devonian limestone carries a high percentage of calcium carbonate. Along Mississippi River and the lower Illinois Valley practically all the limestone quarries are in Mississippian rocks, which are generally well exposed in the bluffs, and consequently economical quarrying sites are not difficult to find. Thus far development has taken place principally at points where railroads happen to be built near good limestone outcrops, although, of course, some quarries have been

opened at a distance and connected with the main line by spur tracks. On Ohio River in southern Illinois Mississippian rocks are also quarried. In eastern Illinois a few quarries have been opened in Pennsylvanian rock, notably a large quarry producing limestone for blast furnace flux and Portland cement in Vermilion County. The Carboniferous rocks generally are fairly high in calcium and low in magnesium, but the Mississippian rocks particularly are apt to contain a considerable percentage of silica, in some places in the form of chert. Lime is made from all these limestones in Illinois.

Indiana is underlain by formations having the same range in age as those in Illinois. The Pennsylvanian rocks outcrop in western Indiana; Mississippian rocks are found in a belt a little west of the middle of the State and in an area in the extreme northeast corner; Devonian and Silurian formations underlie the northwestern, central, and northeastern portions, with Ordovician rocks in the southeast corner, which is affected by the Cincinnati anticline. The limestone quarries in Indiana are chiefly in the Mississippian, Devonian, and Silurian formations. Thirty-eight counties are reported as producers of limestone. Lawrence and Monroe counties are the principal producers of building stone in the State. The famous oolitic limestone quarried about Bedford as a center occurs in these counties in a favorable situation for quarrying. This limestone is of Mississippian age and has few counterparts in the United States so far as its physical characteristics are concerned. This Bedford stone is of medium fine-grained, even texture, and is composed of small round concretionary grains and of broken fragments of fossils, all compactly cemented together by calcite. The stone occurs in masses 30 to 50 feet and even 70 feet thick.

In addition to the counties mentioned Owen, Crawford, Harrison, and Washington counties, Ind., are said to be underlain by this oolitic limestone. In Bartholomew, Decatur, Jennings, and Ripley counties there is considerable quarrying in limestone of Devonian and Silurian age, and farther north, in Delaware, Grant, Wabash, and Huntington counties there are many quarries. This latter area is mainly in magnesian limestone of Silurian age. Some lime is burned from the Silurian limestone in Indiana, but the greater part of the output comes from the high-calcium Mississippian oolitic rock.

In Ohio the limestone quarries are chiefly in three areas which correspond to three geologic systems of rocks. In the northwestern and western parts of the State the quarries are very largely in Silurian magnesian limestone; in southwestern Ohio near Cincinnati rocks of Ordovician age yield limestone low in magnesia but rather high in silica, or in silica and alumina; in eastern Ohio, in Carroll, Stark,

Tuscarawas, and other counties. Pennsylvanian limestones are quarried. These latter rocks are high in calcium carbonate. Lime is burned principally from the magnesian Silurian limestone and from the high-calcium Pennsylvanian beds.

Kentucky is underlain by the same geologic formations that have been mentioned above in Illinois, Indiana, and Ohio. In fact, these four States are more closely associated geologically than any other group of the United States having an equal area. Kentucky has a less area, however, of Silurian rocks, these formations being confined to a narrow strip in central Kentucky around the border of Ordovician rocks that form the Cincinnati anticline. The formations that yield the greater part of the limestone quarried in Kentucky are of Ordovician and Mississippian age. The Ordovician system is represented in the central part of the State southward from Cincinnati, Ohio, and quarries in it are operated in Harrison, Bourbon, Scott, Franklin, Anderson, Fayette, Jessamine, Mercer, Boyle, and other counties. A small quantity of lime is burned in this area. Limestone quarries in Mississippian rocks are scattered pretty well through the southern part of the State, but the most important area is near Bowling Green, Warren County. An oolitic limestone outcrops here, very similar in physical characteristics and of nearly equivalent age to the stone described above occurring in the Bedford (Ind.) district. This oolitic limestone is in a massive, homogeneous stratum 22 feet thick. Other areas of oolitic stone occur near Somerset, Pulaski County, and in Barren, Simpson, Logan, Meade, Hardin, Grayson, Caldwell, Todd, Christian, Wolfe, Powell, and Rockcastle counties and is quarried in a few of them. This oolitic stone has a high content of calcium carbonate and is burned for lime at Bowling Green and several other places.

MINNESOTA.

The limestone areas are mainly in the southeastern part of Minnesota along Mississippi River and westward to the middle of the southern part of the State.

A considerable part of Minnesota is thickly covered with glacial deposits of clay, gravel, and sand. Probably this cover retards the development of quarries to some extent, first, by obscuring outcrops of good rock, and, second, by the expense which its removal entails in quarry operations. The majority of the stone quarries are, therefore, near the streams, where erosion has cut sections through the glacial drift and exposed the hard rock, generally in terraces or bluffs.

Much of the limestone quarried along Mississippi River and its tributaries in Houston, Winona, Wabasha, Goodhue, and Washing-

ton counties is of Cambrian and Lower Ordovician age. The beds are generally highly magnesian and received the name "Magnesian" limestones in early geological reports. They are blue when freshly mined, but weather to a buff color. They lie horizontal and in beds from a few inches to a foot or two in thickness. This belt of rock extends up Mississippi River nearly to St. Cloud and up Minnesota River beyond Mankato; it is quarried extensively near Kasota and Mankato both for building stone and for natural cement and at other places for crushed stone and for the manufacture of lime. Along Mississippi River the limestone is used extensively for riprap.

Overlying the Cambrian and Lower Ordovician rocks in southeastern Minnesota, between Mississippi and St. Peter rivers, are rocks of Middle and Upper Ordovician age, including the so-called "Trenton" limestone. Quarries have been opened in these beds near Rochester, Mantorville, Faribault, and Minneapolis. The color and bedding of these rocks are similar to those of the earlier Ordovician rocks. Near Faribault certain of the limestone beds consist of so nearly pure calcium carbonate that the stone has been burned for the manufacture of lime for use in beet-sugar refining. Most of the material for structural purposes produced from the so-called "Trenton" limestone is used in the form of rubble and crushed rock.

The local surface rock at Minneapolis is the so-called "Trenton" limestone. This rock consists of beds of high-calcium, fine-grained, dense light-gray rock, beds of bluish to greenish argillaceous magnesian limestone, and beds that approach shale in texture. The first-mentioned beds are the most desirable for all purposes, but most of the quarries are obliged to move considerable of the inferior stone, and more or less of it is worked into the product.

Lime is burned from local stone in the following Minnesota counties: Blue Earth, Fillmore, Goodhue, Mower, Rice, and Scott. As noted above, the limestone in most of these counties is magnesian, but that in Rice and Mower counties is high in calcium carbonate. Analyses of certain of these limestones and limes are given in Mineral Resources for 1911, Part II, pages 673 and 701. The magnesian stone is of Ordovician age, earlier than the "Trenton," and the high-calcium stone belongs to the so-called "Trenton" and later formations. The quarry at Le Roy, Mower County, is in an area of Devonian rock.

Limestone is quarried in 16 counties in Minnesota, 6 of which produce lime; and in addition lime is burned near Duluth from stone quarried in Ohio and shipped by boat through the Lakes. As at present developed there are more quarries of limestone in Minnesota than of any other rock, and if the value of the output of lime, as well as of limestone, is considered, the industry based on limestone

quarrying yields more wealth than any other phase of the quarrying industry.

IOWA.

Although a considerable part of the surface of Iowa is covered with glacial drift, streams have so dissected the drift mantle as to produce many good exposures of the underlying beds of hard rock. Paleozoic rocks underlie the eastern two-thirds as well as the southwest corner of the State. Cretaceous rocks underlie the remaining northwestern portion, with the exception of a few square miles in the northwest corner, which are underlain by Huronian (Sioux) quartzite. The Paleozoic rocks, which begin with the Cambrian and Lower Ordovician along Mississippi River, in the northeast corner of the State, outcrop in successive northwest-southeast belts and include rocks of Middle and Upper Ordovician, Silurian, Devonian, and Carboniferous age. The Carboniferous rocks include large areas of Mississippian and Pennsylvanian rocks, and a very small area of probably Permian beds in Webster County. The Cambrian and Ordovician systems comprise beds of magnesian limestone, soft, friable sandstone, and some fairly high calcium limestone; the Silurian and Devonian systems carry magnesian limestone and high-calcium limestone, respectively; the Mississippian series is composed mostly of high-calcium limestone, but some magnesian and some cherty beds and some sandstone; and the Pennsylvanian series contains much sandstone and a smaller proportion of shaly limestone. Most of the systems contain shale, but no account is taken of that material in this connection.

The distribution of stone quarries follows closely that of the streams and incidentally that of the railroads, and also falls almost entirely within the area of Paleozoic rocks. With possibly the exception of limestone quarries in Montgomery County, apparently there are no regularly working quarries in the Cretaceous areas, although doubtless there are a few local pits that produce limited quantities of Cretaceous limestone for use on the farms.

The limestone quarries of Iowa are distributed over the eastern two-thirds of the State and have been opened in each of the Paleozoic limestones mentioned above. Probably the greater number of quarries are in limestone of Mississippian age, although there are numerous quarries in the Cambrian and Ordovician areas. There are about 243 limestone quarries in Iowa in 42 counties. Twenty-three of these quarries in 7 counties produce stone for making lime. High-calcium lime is burned from formations of Mississippian and Devonian age, and magnesian lime is produced from Mississippian and Ordovician rocks.

LOUISIANA.

Practically the whole of Louisiana is within the Coastal Plain, and is underlain by formations of Tertiary and Quaternary age, consisting principally of clay, sand, and soft limestone. Locally there are hard beds of limestone and sandstone in the Tertiary deposits, and if situated conveniently to transportation lines they may be quarried.

The only limestone reported as quarried in Louisiana is near Winnfield, Winn Parish. Hand specimens of this limestone sent to the Survey are of a dense, subcrystalline, bluish limestone, gashed and seamed with white calcite veins from the thickness of a knife blade up to three-fourths of an inch. The material makes a good crushed stone for ballast, macadam, and concrete. An analysis published in Mineral Resources for 1911 shows nearly 92 per cent calcium carbonate, and the material is probably suitable for the manufacture of lime.

DISTRIBUTION OF PEAT DEPOSITS AND QUANTITY OF PEAT AVAILABLE.

GENERAL FEATURES.

The most valuable peat deposits of this country may be roughly assigned to two general regions—the northern or glacial, and the Atlantic coastal—and this division, though partly geographic, indicates the chief differences in origin and in the quality of the peat. The northern peat region, which contains the most extensive deposits in the United States, includes Minnesota, Wisconsin, Michigan, eastern South Dakota, the northern parts of Iowa, Illinois, Indiana, and Pennsylvania, and New York, New Jersey, and the New England States. (See Pl. I.) This region is characterized by numerous ponds, marshes, and lakes formed by glacial action during Pleistocene time and by relatively low temperature and high humidity in the growing season. Most of the peat originated in basins. Probably the largest peat deposit in this country is in the northern region. It covers nearly 4,000 square miles, or about 2,500,000 acres, in Beltrami, Koochiching, Roseau, and Marshall counties, Minn. The Great Lakes States contain a larger quantity of high-grade workable peat than all other States. New England has many climbing bogs and much sphagnum peat, and the most extensive deposits occur in Maine and Massachusetts. It is estimated that in Maine alone there are deposits which would yield 100,000,000 short tons of air-dried peat, 48,000,000 tons of which are readily accessible. New England peat is of good quality.

The Atlantic coastal region, which contains many workable deposits, embraces the southern part of Delaware, the eastern parts of

Maryland, Virginia, North Carolina, South Carolina, and Georgia, and all of Florida. The nearness of the ocean causes heavy rainfall and high relative humidity in this region, and the deposits occur in drowned valleys and lagoons, which were formed by the gradual subsidence of the Coastal Plain and by wave action, and on flat, imperfectly drained areas farther inland. This region is characterized by many salt and fresh water marshes and swamps, in which the deposits have been formed largely by trees, sedges, and marsh grasses, some of the grasses tolerating salt water around their roots. The largest deposits of good peat in this region are in Virginia, North Carolina, and Florida.

Although there are a few peat deposits along the coasts of the New England States and New Jersey that are related in origin and composition to those assigned to the Atlantic coastal region, by far the most numerous bogs of the Northeastern States are of the filled-basin kind, and these States are therefore classed in the northern region.

Peat also occurs in a narrow belt of land adjoining the Gulf Coast, in Siskiyou, Los Angeles, Orange, and San Bernardino counties, Calif., in the valleys of Sacramento and San Joaquin rivers, and in the basis of several lakes and rivers in Oregon and Washington.

In 1909 the total quantity of known peat in the United States, exclusive of Alaska, calculated as air-dried peat, was estimated to be 12,889,000,000 short tons,[21] but recent field investigations seem to justify an increase of this figure to 13,827,000,000 tons, distributed as follows:

Approximate distribution of known peat in the United States, by States (estimated as air-dried peat).

State.	Area (acres).	Quantity (short tons).
Northern region:		
Minnesota	5,217,000	6,835,000,000
Wisconsin	1,000,000	2,500,000,000
Michigan		1,000,000,000
Iowa		23,000,000
Illinois	42,000	10,000,000
Indiana		12,000,000
Ohio	50,000	50,000,000
Pennsylvania		1,000,000
New York	800,000	480,000,000
New Jersey		15,000,000
Maine		100,000,000
New Hampshire		1,000,000
Vermont		8,000,000
Massachusetts		12,000,000
Connecticut		2,000,000
Rhode Island		1,000,000
		11,050,000,000

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[21] Davis, C. A., Peat resources of the United States exclusive of Alaska: U. S. Geol. Survey Bull. 394, pp. 65–66, 1909.

A. SPRUCE-SPHAGNUM BOG.

B. TAMARACK SWAMP.

PREDOMINANT TYPES OF PEAT DEPOSITS IN NORTHERN MINNESOTA.

Approximate distribution of peat in the United States, by States—Continued.

State.	Area (acres).	Quantity (short tons).
Atlantic coastal region:		
Virginia and North Carolina		700,000,000
Florida		2,000,000,000
Other States[a]		2,000,000
		2,702,000,000
Other regions:		
Gulf Coast[b]		2,000,000
California	60,000	72,000,000
Oregon and Washington		1,000,000
		75,000,000
Grand total		13,827,000,000

[a] Includes Delaware, Maryland, South Carolina, and Georgia.
[b] Exclusive of Florida.

NORTHERN REGION.

MINNESOTA.

The peat deposits in Minnesota, which are the most extensive in the United States, occur in basins that are of glacial origin. The largest of these basins are in the area that was covered by the waters of glacial Lake Agassiz and of other temporary glacial lakes. Besides these there are many deposits in ponds, marshes, and swamps in the smaller basins in the glacial drift. Most of the large filled-basin deposits matured long ago and are covered with built-up peat. Most of the peat occurs in spruce and tamarack swamps, known locally by the Indian term "muskeg." (See Pl. V.) Cedar swamps are also common. Sphagnum moss, sedges, grasses, and heath shrubs are the most notable plants that grow in the open areas. The greater part of the sphagnum is unsuitable for surgical use, and good moss for this purpose was found only in the vicinity of Cohasset, Coleraine, Deer River, Warba, and Wawina, Itasca County; Littlefork, Margie, Nakoda, and Wisner, Koochiching County; and Elmer, Floodwood, Island, and Wallace, St. Louis County. The most extensive peat deposits lie in the northern part of the State; but some peat occurs in nearly every county except in the Red River district of western Minnesota and the Driftless Area in southeastern Minnesota. However, the deposits of workable extent may be roughly assigned to the three areas described below:

1. The northern area includes the "muskeg" swamps of Aitkin, Beltrami, Cass, Clearwater, Crow Wing, Itasca, Koochiching, Roseau, and St. Louis counties. (See Pl. VI.) This area contains more peat than any other of equal size in the United States. There are about 1,300,000 acres of peat land in Beltrami County alone. Koochi-

ching and St. Louis counties each contain at least 1,000,000 acres of peat, most of which exceeds 6 feet in depth.

2. The central area embraces Anoka, Chisago, Douglas, Hennepin, Isanti, Mille Lacs, Ramsey, Sherburne, Washington, and Wright counties. The deposits of Anoka County, within a few miles of Minneapolis and St. Paul, contain a large quantity of good peat.

3. The southern area includes Blue Earth, Carver, Dakota, Freeborn, Le Sueur, Nicollet, Rice, Scott, Steele, and Waseca counties. The deposits in this area are relatively small and shallow.

It is estimated that the deposits of Minnesota are capable of yielding 6,835,000,000 short tons of air-dried peat, the distribution of which, by counties, is shown in the following table:[22]

Area and depth of peat in Minnesota, and quantity available as air-dried peat, by counties.

County.	Area (acres).	Average thickness (feet).	Quantity (short tons).
Aitkin	397,300	6	476,760,000
Anoka	30,000	7	42,000,000
Becker	12,800	5	12,800,000
Beltrami	1,299,200	7	1,818,580,000
Carlton	35,000	10	70,000,000
Cass	75,000	5	75,000,000
Clearwater	128,000	5	128,000,000
Crow Wing	61,300	6	73,560,000
Douglas	5,000	6	6,000,000
Hubbard	10,000	6	12,000,000
Isanti	10,000	5	10,000,000
Itasca	250,000	6	300,000,000
Koochiching	1,000,000	7	1,400,000,000
Lake	150,000	6	180,000,000
Marshall	50,000	5	50,000,000
Mille Lacs	25,000	5	25,000,000
Morrison	10,000	5	10,000,000
Otter Tail	75,000	5	75,000,000
Pennington	10,000	5	10,000,000
Pine	75,000	5	75,000,000
Ramsey	1,500	5	1,500,000
Roseau	250,000	5	250,000,000
St. Louis	1,192,000	7	1,668,800,000
Todd	10,000	5	10,000,000
Wadena	5,000	5	5,000,000
Other counties	50,000	5	50,000,000
	5,217,100	....	6,835,000,000

Information concerning the chemical composition of this peat is given in the tables of analyses (pp. 37–42). Nearly all the accessible peat deposits in Minnesota are described in detail in Bulletin 16 of the Minnesota Geological Survey.

WISCONSIN.

Most of the peat deposits of Wisconsin, like those of Minnesota, occupy depressions formed by glacial action during the Wisconsin stage of glaciation. Large spruce-sphagnum and tamarack-sphagnum

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[22] Soper, E. K., The peat deposits of Minnesota: Minnesota Geol. Survey Bull. 16, p. 33, 1919.

MAP OF WISCO

Pa

ogs and swamps predominate in the northern part of the State, nd many grass-sedge meadows and marshes occur in the southern part. The deposits that have been tested range from 1 to 20 feet in depth and from 1 to 32,000 acres in area. Much peat in northern Wisconsin has been destroyed by fire, and the charred remains, deeply buried in some places beneath thick fibrous peat, indicate that the conflagration occurred thousands of years ago. Many areas have been only recently damaged by fire, and the underlying peat is covered with 2 or 3 feet of charred material. In some places the arlier vegetation has been destroyed, and entirely different plants have succeeded.

The general distribution of undrained land in Wisconsin is shown in Plate VII. Valuable peat deposits are found throughout the State except in the southwestern part. There is some peat in nearly ll the undrained areas, but the most valuable deposits are in the following counties: Ashland, Dane, Dodge, Door, Florence, Fond du Lac, Green Lake, Jefferson, Juneau, Kewaunee, Langlade, Marinette, Marquette, Oconto, Oneida, Price, Rock, Sawyer, Shawano, Sheboygan, Vilas, Walworth, Waukesha, Waupaca, Waushara, Winnebago, and Wood. A detailed description of the areas that have been tested for peat is given in a State report.[23]

It is estimated that there are a little more than 1,000,000 acres of peat land in Wisconsin capable of yielding 2,500,000,000 short tons of air-dried peat. The following table[24] shows the distribution, creage, depth, and contents of 50 deposits that have been examined by the Wisconsin Geological and Natural History Survey. The approximate location of these deposits, which include a little more than ne-tenth of the total area of peat in the State, is shown in Plate VII. The chemical composition of the peat is shown in the table f analyses (pp. 51–57).

Area, depth, and contents of typical peat deposits in Wisconsin.

eposit No.	Location (nearest town or city).	Area (acres).	Depth (feet).	Acre-feet.	Quantity of air-dried peat (short tons).
1	Stoughton	520	9	4,680	936,000
2	Whitewater	640	9	5,760	1,152,000
3	.....do.	200	7	1,400	280,000
4	.....do.	12,800	5	64,000	12,800,000
5	Lake Beulah	500	12	6,000	1,200,000
6	Dousman	9,600	3	28,800	5,760,000
7	Madison, Lake Wingra	100	2½	250	50,000
8	Glenbeulah	9,600	9	86,400	17,280,000
9	Medina	6,400	12	76,800	15,360,000
10	Eldorado	4,000	8	32,000	6,400,000
11	Chester	32,000	6	192,000	38,400,000
12	Mendota	1,300	10	13,000	2,600,000

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[23] Huels, F. W., The peat resources of Wisconsin: Wisconsin Geol. and Nat. Hist. Survey ull. 45, pp. 82–144, Econ. Ser. 20, 1915.

[24] Idem, p. 170.

Area, depth, and contents of typical peat deposits in Wisconsin—Continued.

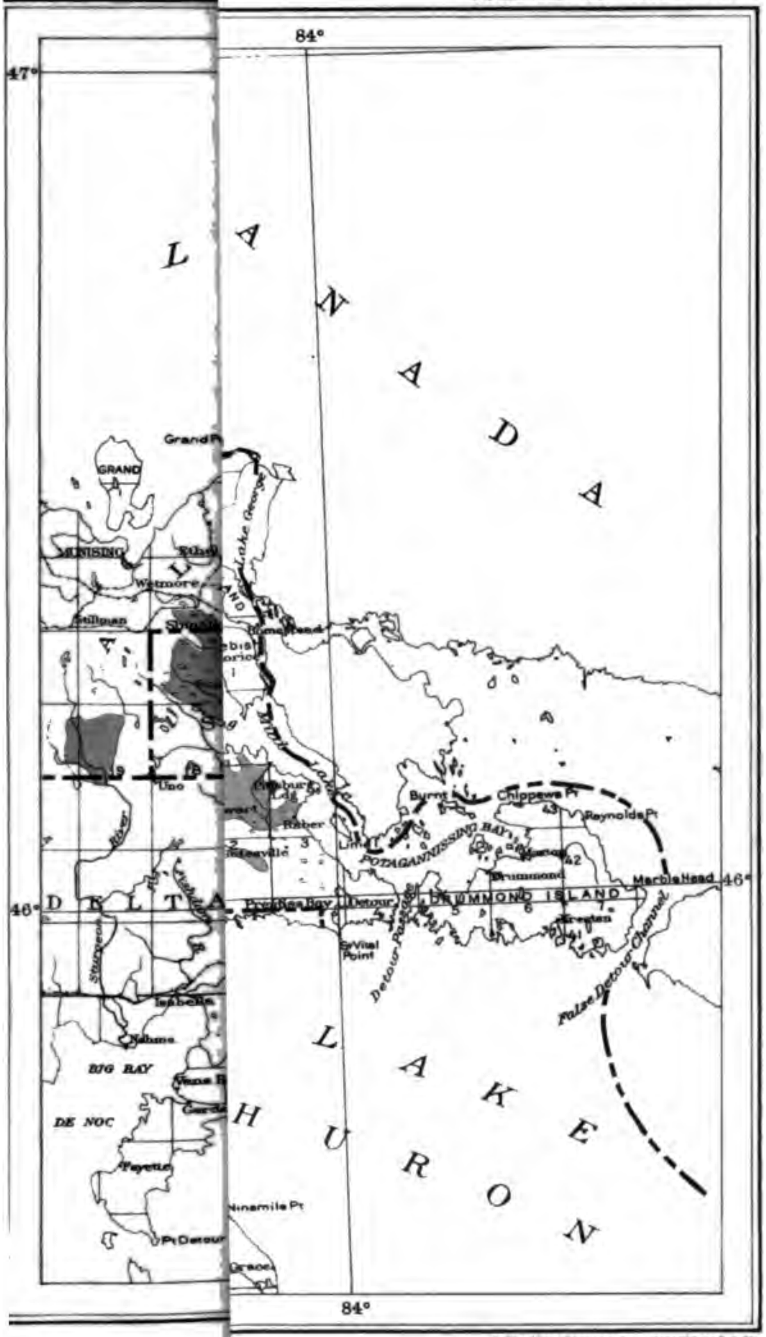
Deposit No.	Location (nearest town or city).	Area (acres).	Depth (feet).	Acre-feet.	Quantity of air-dried peat (short tons).
13	Markesan	....	12	....	....
14	Marshall	....	....	....	....
15	Rhinelander	1,200	6	7,200	1,440,000
16	Camp Douglas	2,000	2	4,000	800,000
17	Babcock	....	....	....	....
301	Mendota, Yahara River	500	7	3,500	700,000
302	Madison, University Bay	100	6	600	120,000
303	Fond du Lac	800	7	5,600	1,120,000
304	Waupaca	1,500	10	15,000	3,000,000
305	....do	60	20+	1,200	240,000
306	Kiel, Manitowoc	10,000	8	80,000	16,000,000
307	....do	....	....	....	....
308	Kiel	....	6	....	....
309	Kiel, Sheboygan	5,500	4	22,000	4,400,000
310	Bloomer	2,000	3	6,000	1,200,000
311	....do	10	6	60	12,000
[a]312	Ashland	80	8	640	128,000
313	Hayward	40	16	640	128,000
314	....do	200	10	2,000	400,000
315	New Auburn	1,000	8	8,000	1,600,000
316	Cameron	500	14	7,000	1,400,000
317	Ladysmith	40	4	160	32,000
318	Heafford Junction	80	20	1,600	320,000
319	Minocqua	40	6	240	48,000
320	....do	80	16	1,280	256,000
321	Lac du Flambeau	15,000	4	60,000	12,000,000
322	Powell	100	8	800	160,000
323	Glidden	300	14	4,200	840,000
324	Park Falls	60	5	300	60,000
325	Kewaunee	800	6	4,800	960,000
326	Algoma	30	3	90	18,000
327	Sturgeon Bay	150	14	2,100	420,000
328	Peshtigo	500	2	1,000	200,000
329	Pembine	80	6	480	96,000
330	Gagen	200	9	1,800	360,000
331	Eagle River	500	9	4,500	900,000
332	Antigo	50	1½	75	15,000
333	Mountain	60	3½	210	42,000
		121,220	....	758,165	151,633,000

[a] Includes muck.

MICHIGAN.

GENERAL FEATURES.

The peat deposits of Michigan consist largely of "muskegs" and grass-sedge marshes in basins of glacial origin and are similar in most respects to those of Minnesota and Wisconsin. Except in Ontonagon and Baraga counties and in the southern part of Houghton County, peat is well distributed throughout the northern peninsula, but, as shown by Plate VIII, the most extensive deposits are in the eastern part of that peninsula. The largest swamps, some of which exceed 25 square miles in area, lie in a region about 90 miles long and 30 miles wide extending eastward from Munising toward Sault Ste. Marie. The peat in these swamps ranges from 2 to 20 feet in depth. Although there are many peat deposits in the southern peninsula of Michigan, few exceed 400 acres in area. The largest deposits occur in river valleys, and consequently contain a high percentage of ash. However, large quantities of good peat are found



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in nearly all the lakes in the northern part of the southern peninsula. It is estimated that Michigan could yield 1,000,000,000 short tons of air-dried peat and that 80 per cent of this quantity is in the northern peninsula. Many peat deposits in Michigan have been described in detail by Charles A. Davis,[25] and many of the data presented herein are based upon his work. The deposits examined for this report are described below. The localities are indicated by their numbers on Plate VIII.

DICKINSON COUNTY.

Locality 1.—A deposit in the NE. ¼ sec. 7 and the NW. ¼ sec. 8 of Norway Township, which is about 130 acres in area and 5 feet deep, is estimated to be capable of yielding approximately 130,000 short tons of air-dried peat. The living vegetation consists chiefly of sedges and grasses, though scattered coniferous trees grow at the south end of the deposits. The peat is dark brown, well decomposed, and of relatively uniform texture and is underlain by sand. A typical sample (analysis 383, p. 35) was obtained by mixing peat taken from several test borings. As the ash content is 17.41 per cent and the nitrogen 1.89, the peat appears to be suitable for the production of only low-grade fuel and fertilizer.

EATON COUNTY.

Locality 2.—A deposit about 2½ miles east of Eaton Rapids, near the track of the Michigan Central Railroad, which is about 400 acres in area and 7 feet deep, would probably yield 560,000 short tons of air-dried peat. The peat is brown and fibrous, consists chiefly of the remains of grasses and sedges, contains many roots and pieces of wood, and is underlain by sand. The dominant living vegetation consists of grasses and sedges. The deposit has been well drained, and part of it is used for the growth of cabbage. Two typical samples (see analyses 351 and 352, p. 35) were obtained by mixing peat taken from several test holes. A comparison of these analyses shows that the peat is comparatively uniform in quality. As the nitrogen content is high and the percentage of ash relatively low, the peat might be profitably used either as fuel or as an ingredient of fertilizer.

HOUGHTON COUNTY.

Locality 3.—A large bog in the Sturgeon River Valley near Klingville, which is 16 miles long and 2 to 2½ miles wide and about 36 square miles in area, contains a deposit of peat 5 feet deep, which is estimated to contain the equivalent of 23,000,000 short tons of air-

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[25] Davis, C. A., Peat; essays on its origin, uses, and distribution in Michigan: Michigan Geol. Survey Rept. for 1906, pp. 93-395, 1906.

dried muck and peat. The deposit was sampled at points along a line extending from east to west through its center. Samples were also collected near the main drainage ditches along lines run at right angles to the other series of test borings. The upper 3 feet of peat is mossy and fibrous and contains many roots and pieces of wood; the lower layers are brown, well decomposed, soft, and plastic. The living vegetation consists chiefly of sphagnum moss, although tamarack, spruce, and swamp laurel are common. The deposit has been partly drained, and about 300 acres have been cleared. A representative sample (analysis 372, p. 35) was obtained by mixing muck and peat taken at intervals of 2 feet in depth in eight test holes. Analyses 373 and 375 (p. 35) or both the raw and macerated muck and peat show that they contain too much ash for fuel. The nitrogen content is a little less than 2 per cent and is relatively uniform throughout the deposit.

Locality 4.—In a small bog in the NE. ¼ sec. 22 and the NW. ¼ sec. 23, Calumet Township, the living vegetation consists chiefly of tamarack and small poplar trees, although it includes some tufts of sphagnum moss. The peat is brown and fibrous and contains much woody material. Four test borings were made, and a typical sample (analysis 378, p. 35) was obtained by mixing peat taken from each. The general appearance of this bog is misleading. Its topographic position and flora justify the assumption that it contains a large quantity of peat, but test borings show only a shallow accumulation of fibrous plant remains. There are many peat bogs of this type in the vicinity of Calumet and Osceola.

Locality 5.—A small bog near the tracks of the Duluth, South Shore & Atlantic Railway, west of the Hecla mine, contains a deposit which is 15 acres in area and 12 feet in average thickness. The upper layer of the peat has shrunk, producing an open fissure and exposing a cross section of the deposit. The peat consists chiefly of remains of grass, is brown, coarse, and fibrous, and is underlain by sand. A sample (analysis 379, p. 35) was obtained from the exposed section. As its nitrogen content is unusually high (2.53 per cent), the peat might be used as fertilizer, but though its ash content is low fuel could not be economically made from it, because the bog has been drained to the bottom and the peat is too dry and fibrous to be shaped into blocks.

IRON COUNTY.

Locality 6.—A small bog near the center of sec. 22, T. 43 N., R. 32 W., contains a deposit about 6 acres in area and 4 feet deep. The living vegetation consists chiefly of sedges and sphagnum. The peat, which is composed of the remains of plants like those growing

in the bog, is brown, fibrous, and woody. Analysis 380 (p. 35) shows the quality of the peat in this bog. Similar bogs occupy small depressions, known as kettle holes, in this vicinity.

Locality 7.—A deposit in the NW. ¼ sec. 21 and the SW. ¼ sec. 16, Crystal Falls Township, is about 90 acres in area and 3 feet deep. The living vegetation consists chiefly of sedges and reeds, though some trees grow at the north end. The peat is dark brown and well decomposed but not plastic, and consists chiefly of the remains of sedges and reeds. Four test borings were made at intervals of 100 yards at points along a line extending from north to south through the center. An average sample (analysis 381, p. 35) was obtained by mixing peat taken at several depths from each of the test holes.

Locality 8.—A bog east of Ice Lake in the NE. ¼ sec. 30, the western part of sec. 29, the SE. ¼ sec. 19, and the SW. ¼ sec. 20, Bates Township (T. 43 N., R. 34 W.) is about 120 acres in area and 3 feet in average depth. The deposit is composed chiefly of the dark-brown and fibrous remains of mosses, reeds, and sedges. The living vegetation consists principally of sphagnum and heath shrubs. A typical sample (analysis 382, p. 35) was obtained by mixing material taken from numerous test holes. The high content of inorganic mineral matter (41.55 per cent) shows that the deposit contains muck which is unfit for fuel.

KALAMAZOO COUNTY.

Locality 9.—A deposit near the Grand Rapids & Indiana Railway north of Vicksburg, which is about 400 acres in area and 5 feet in average depth, is capable of yielding 400,000 short tons of air-dried peat and muck. The surface layer consists of black muck, and the underlying peat ranges from brown to black, is rather fibrous, and is underlain by sand. It occupies a basin-shaped depression that would be difficult to drain. The living vegetation consists chiefly of sedges and grasses. A representative sample (analysis 347, p. 35) was obtained by mixing peat and muck taken from four test borings made at points along a line crossing the middle of the deposit. The heating value of the moisture-free peat is 8,203 British thermal units, the ash content 12.71 per cent, and the nitrogen 3.58 per cent. The peat, therefore, seems well adapted for fuel or fertilizer.

Locality 10.—A deposit on the Kleinstueck estate, in the southern part of the city of Kalamazoo, is about 30 acres in area and 6 feet in average thickness. The peat is brown and rather fibrous and is underlain by sand. Several test borings were made near the center of the deposit, and a representative sample (see analysis 350, p. 35) which was obtained by mixing peat from each of the test holes, shows that the peat is of excellent quality for fuel or fertilizer. Analyses 348 and

349 (p. 35) show the quality of dried and pressed peat from this deposit. A comparison of these analyses shows that the deposit contains peat of relatively uniform composition.

LAPEER COUNTY.

Locality 11.—A deposit south of the Grand Trunk Railway tracks, a short distance east of Imlay City, is about 200 acres in area and 8 feet in average depth. The living vegetation consists chiefly of grasses and sedges and near the south end of scattered tamarack trees. The peat is dark-brown, well-decomposed, and plastic, contains some woody matter, and is underlain by sand. Three test holes were made at intervals of 100 yards across the south end. A representative specimen (analysis 357, p. 35) was obtained by mixing peat taken at intervals of 2 feet in depth, from each of these borings. The calorific value of the moisture-free peat is 9,186 British thermal units and the nitrogen content 2.24 per cent. The peat should therefore make good fuel and fertilizer.

LUCE COUNTY.

Locality 12.—A bog near the Duluth, South Shore & Atlantic Railway west of Newberry, about 150 acres in area, contains a deposit of peat 4 feet in average depth. The peat consists chiefly of the remains of sedges and moss, contains several thin layers of woody material, and is dark brown and well decomposed. The living vegetation consists of spruce, tamarack, sedges, sphagnum, and numerous varieties of small shrubs. A typical sample (analysis 369, p. 35) was obtained by mixing peat taken at different depths from four test holes made across the center of the bog.

Locality 13.—A large swamp north of Newberry, which is several hundred acres in area, contains peat only 2 feet in average depth. The living vegetation consists of spruce, tamarack, and a dense growth of shrubs. The peat, which was produced chiefly by the decay of sedges and grasses, is dark brown to black, is well decomposed, and is underlain by sand. Analysis 370 (p. 35) shows that the peat is of rather poor quality.

MARQUETTE COUNTY.

Locality 14.—A bog in the northern part of the city of Marquette, near the shore of Lake Superior, about 300 acres in area, contains a deposit of peat 2 feet in average thickness. The living vegetation consists chiefly of grass, moss, and scattered coniferous and poplar trees. The peat is black and ranges in texture from fibrous to plastic. Analysis 371 (p. 35) shows that it is fair in quality, but the deposit is probably too shallow to be of economic value.

MECOSTA COUNTY.

Locality 15.—A large swamp north and east of the village of Mecosta contains a deposit of peat about 3,500 acres in area and from 4 to 16 feet in thickness. This deposit is capable of yielding approximately 4,900,000 short tons of air-dried peat and muck. The peat and muck are dark brown, fibrous, and woody and are underlain by sand and marl. The living vegetation consists chiefly of poplar, spruce, and tamarack trees. As there is a dense undergrowth of small shrubs, the swamp is difficult to penetrate. The surface is thickly covered with old logs, stumps, slashings, chips, and other débris of logging operations. A series of test borings was made at intervals of 100 yards along an east-west line across the center of the swamp. Representative samples (analyses 365, 366, 367, 368, p. 35) were obtained from these test borings by mixing material taken at different depths. A comparison of the analyses shows that the deposit contains too much ash for good fuel. The nitrogen content, which ranges from 1.42 per cent to 1.97 per cent, is also low. The high sulphur content (3.48 per cent in analysis 366) is noteworthy.

MUSKEGON COUNTY.

Locality 16.—A muck marsh along Muskegon River, in the northeastern part of Muskegon Township, contains a deposit of peat 3,000 acres in area and 5 feet in average thickness. The depth, however, is variable, and small pockets were encountered in sampling the deposit in which the organic matter was much more than 5 feet deep. The living vegetation consists of a heavy growth of marsh grass and bulrushes. At the north end of the marsh beech and willow trees are numerous. The muck is brown and fibrous and contains a large percentage of inorganic material, owing to the large quantities of sand deposited by Muskegon River during floods. The recurrent floods which have covered this area are recorded in the deposit by alternate layers of sand and organic matter. Numerous test borings were made along both the north and south sides of the marsh and a representative sample (analysis 364, p. 35) was obtained by mixing material taken from the test holes. According to the analysis, the sample contains 58.32 per cent of ash and 1.57 per cent of nitrogen, and is therefore to be classed as muck rather than peat. Louis P. Haight, of Muskegon, is reclaiming this marsh for agricultural use.

OAKLAND COUNTY.

Locality 17.—A deposit near the center of sec. 32, in the southern part of Pontiac, occupies an area of about 40 acres and is 2½ feet in average depth. The living vegetation consists of sedges and

reeds. The peat is dark brown, well decomposed, and plastic, consists principally of the remains of sedges, and is underlain by marl. Several borings were made throughout the area, and a representative sample (analysis 356, p. 35) was obtained by mixing the peat from the test holes. The peat contains an unusually large proportion of nitrogen (3.22 per cent) but is not thick enough to be workable commercially.

ST. CLAIR COUNTY.

Locality 18.—A large marsh on the Grand Trunk Railway 3 miles west of Capac contains a deposit about 3,000 acres in area and 7 feet in average depth. The peat is brown and fibrous and is underlain by sand. The living vegetation consists chiefly of grasses, sedges, reeds, and the blueberry. Representative specimens (analyses 358, 359, 360, p. 35) were obtained by mixing peat taken at numerous places along the drainage ditch that extends longitudinally across the marsh. The peat is low in ash and high in calorific value, but it is too fibrous for the manufacture of machine-peat fuel.

SHIAWASSEE COUNTY.

Locality 19.—A bog about 2 miles west of Bancroft, which is 300 acres in area, contains a deposit 5 feet in average thickness. The living vegetation consists chiefly of sedges, grasses, reeds, bulrushes, and tamarack trees. The peat is dark brown to black, well decomposed, and plastic, and is underlain by impure marl and sand. Numerous test borings were made through the center, and composite samples (analyses 361, 362, 363, p. 35) were obtained by mixing peat from each of the test holes. The peat appears to be of good quality for fuel or for fertilizer.

WASHTENAW COUNTY.

Locality 20.—A bog in the southern part of Chelsea, about 100 acres in area, contains a deposit of peat 3 feet in average depth. The living vegetation consists chiefly of grasses, mosses, and the blueberry. The peat is brown, fibrous, and flaky and is underlain by impure marl and sand. Test borings were made at intervals of 50 yards across the center of the bog, and typical samples (analyses 353, 354, 355, p. 35) were obtained by mixing peat taken from each hole. A comparison of the analyses shows the peat is uniform in composition and appears to be of the proper quality for fuel or fertilizer, but it is probably too shallow for commercial use.

IOWA.

The principal peat deposits in Iowa occur in the Altamont morainal belt of the Wisconsin glacial drift and are largely confined

to the north-central part of the State. Cerro Gordo, Clay, Dickinson, Emmet, Franklin, Hamilton, Hancock, Kossuth, Palo Alto,

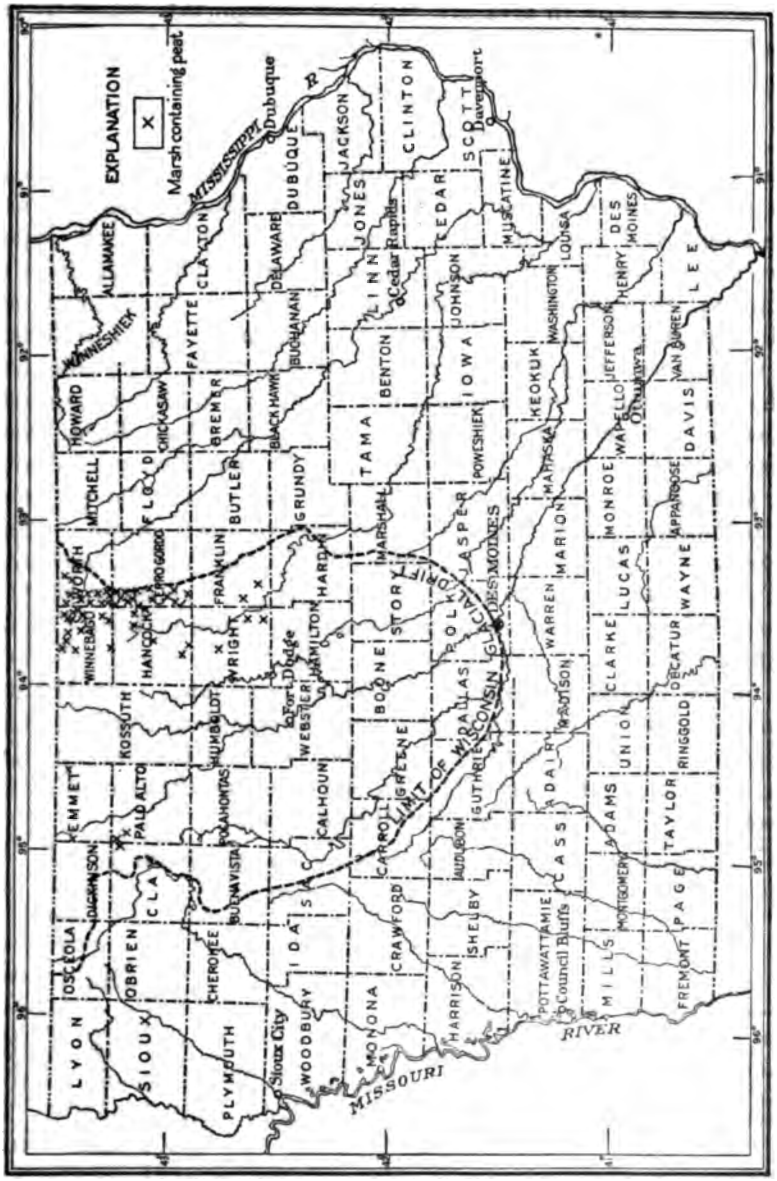

FIGURE 2.—Map of Iowa showing area covered by the Wisconsin glacial drift and approximate location of deposits that have been tested for peat (X).

Webster, Winnebago, Worth, and Wright are the counties in which **peat deposits are most extensive.** (See fig. 2.) Most of the peat **was formed in open grass-sedge** marshes and in shallow lakes and **ponds. Sphagnum** and other mosses were not large contributors to peat in **Iowa.** The deposits range from 1 to 150 acres in area and

from 1 to 20 feet in depth. Savage[26] estimates that Iowa peat bogs would yield 22,000,000 short tons of air-dried peat. The deposits that exceed 40 acres in area are described in reports[27] issued by the Iowa Geological Survey. (See p. 29 for analyses.)

ILLINOIS.

GENERAL FEATURES.

The peat deposits of Illinois originated in hollows in the glacial drift and in lowlands near lakes and rivers. Grassy meadows and grass-sedge and cat-tail marshes are the most common types. There are no wooded swamps in Illinois comparable with those of Minnesota, Wisconsin, and Michigan. Most of the deposits are small, but several that exceed 1,000 acres in area are found in Whiteside County and in a few other parts of the State. The thickness of the peat ranges from 2 inches to 20 feet, but the average depth of most of the deposits is less than 5 feet. Du Page, Kane, Kankakee, Lake, Lee, McHenry, Mason, Rock Island, Tazewell, Whiteside, and Winnebago counties contain practically all the workable peat in Illinois. Although the largest area of peat, known as Cattail Slough, is in Whiteside County, in Cattail Valley, southeast of Fulton, more peat occurs in Lake than in any other county. Plate IX shows the distribution of peat and muck in Lake County and figure 3 (p. 111) shows Cattail Valley in Whiteside County. One of the largest deposits in the State is situated near Manito, Mason County. According to the most reliable data available Illinois peat bogs would yield about 10,000,000 short tons of air-dried peat, the distribution of which in the counties that contain the largest quantities is shown in the following table:[28]

Distribution of peat and muck in six counties of Illinois.

County.	Area.	
	Square miles.	Acres.
Du Page	6.54	4,186
Kane	14.53	9,299
Kankakee	2.73	1,747
Lake	38.10	24,384
Tazewell	2.10	1,344
Winnebago	2.23	1,427
	66.23	42,387

The following localities were tested for peat in the course of field work for this report:

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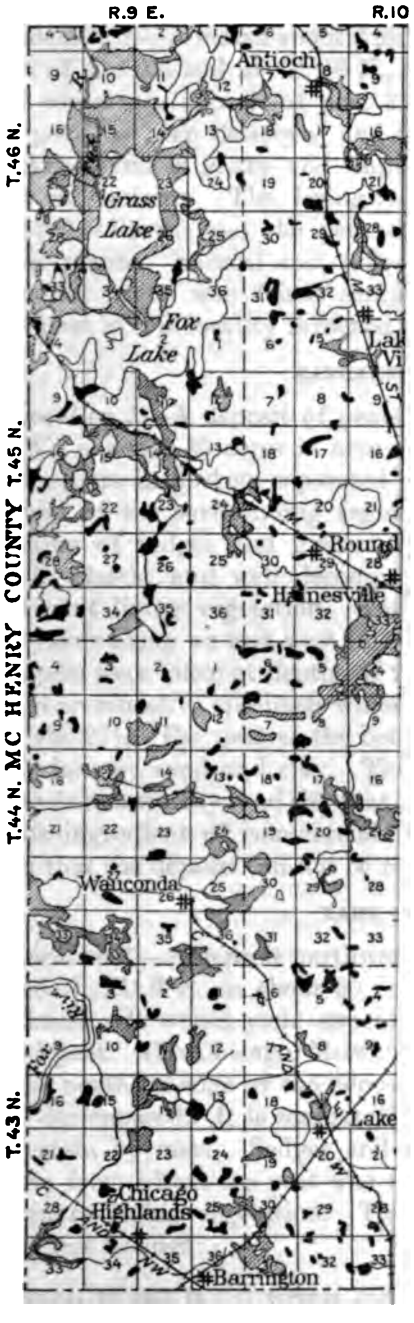
[26] Savage, T. E., A preliminary report on the peat resources of Iowa: Iowa Geol. Survey Bull. 2, p. 8, 1905.

[27] Beyer, S. W., Peat deposits in Iowa: Iowa Geol. Survey Ann. Rept., vol. 19, pp. 689–730, 1908. Savage, T. E., op. cit.

[28] Hopkins, C. G., Mosier, J. G., Van Alstine, E., and Garrett, F. W., Illinois Univ. Agr. Exper. Sta. Soil Repts. Nos. 9, 12, 13, 14, 16, 17, etc., 1915–1917.



MAP SHOWING DISTRIBUTION OF

KANE COUNTY.

Locality 1.—A marsh about 2 miles south of Aurora which occupies part of secs. 26 and 27, T. 38 N., R. 8 E., is about 120 acres in area and contains a deposit of peat 3 feet in average depth. Much of the peat has been destroyed and the remainder is very irregular in thickness and is gritty and impure because of the sand and clay that it contains. The living vegetation is sedges, grasses, and stunted willows, and the peat consists chiefly of the remains of these plants. Several test holes were made, but as no peat of economic value was found samples were not taken for analysis. The peat in this locality is owned by H. H. Evans, of Aurora, Ill.

KANKAKEE COUNTY.

Locality 2.—A deposit of peat in the SW. ¼ sec. 35, T. 32 N., R. 11 W., is about 80 acres in area and 4 feet in average depth. The peat occurs in pockets separated by areas of dry land, a condition typical of the surrounding region. It is composed chiefly of the remains of sedges and grasses and, except the surface layer, is black, plastic, and well decomposed. Grasses and sedges are the dominant living vegetation. Test holes were sunk at intervals of 100 yards along an east-west line crossing the center of the deposit. Samples were taken at depths of 2 feet and mixed in order to obtain the representative specimen whose composition is shown in analysis 317 (p. 27). The peat at the bottom of the deposit is black and is underlain by sand and clay. The high nitrogen content (3.03 per cent) is noteworthy, and the peat appears to be valuable as a nitrogenous ingredient of commercial fertilizers. The ash content is so high that the deposit can not be recommended as a source of fuel.

LAKE COUNTY.

Locality 3.—A deposit northwest of Duck Lake, in secs. 14 and 15, T. 45 N., R. 9 E., is about 90 acres in area and 6 feet in average thickness. It would yield approximately 108,000 short tons of air-dried peat. The Chicago, Milwaukee & St. Paul Railway is parallel to the northern edge of the deposit. The peat is black, plastic, and well decomposed. It is comparatively free from sand and silt and is underlain by marl. Sedges and grasses contributed the vegetable débris from which the peat was formed and also constitute the predominant living vegetation. The following results were obtained from test borings:

Thickness of peat in test borings northwest of Duck Lake, Lake County, Ill.

	Feet.
Hole A, 50 yards from west edge: Black plastic well-decomposed peat	5
Hole B, 100 yards east of hole A: Black plastic well-decomposed peat	7

Samples were taken at intervals of 2 feet in depth and mixed to obtain a representative specimen (analysis 300, p. 27). The nitrogen content (3.84 per cent) is unusually high, and the ash content (15.14 per cent) relatively low. This deposit is well situated with respect to transportation facilities and market, possesses good qualities for fertilizer, and therefore offers an excellent opportunity for commercial development.

Locality 4.—A deposit south of Fox Lake, in the NW. ¼ sec. 11, T. 45 N., R. 9 E., is about 80 acres in area, 10 feet in average thickness, and would yield 160,000 short tons of air-dried muck. The muck is black, plastic, and well decomposed and consists chiefly of the remains of sedges and grasses. These plants also constitute the dominant living vegetation. The following test borings were made:

Thickness of muck in test borings south of Fox Lake, Lake County, Ill.

	Feet.
Hole A, 20 yards east of west edge: Black plastic well-decomposed muck	8
Hole B, 100 yards east of hole A: Black plastic well-decomposed muck	12

A composite specimen (analysis 301, p. 27) was obtained by mixing samples of muck taken at intervals of 2 feet in depth in each hole. The ash content (47.40 per cent) is high, and the muck is therefore valueless for fuel, but the nitrogen content, which is 2.18 per cent, indicates that the material might be valuable for use as a nitrogenous ingredient of commercial fertilizers.

Locality 5.—A deposit near the railroad station at Antioch, between Silver Lake and the tracks of the Minneapolis, St. Paul & Sault Ste. Marie Railway, which occupies parts of secs. 8, 9, 16, and 17, T. 46 N., R. 10 E., is several hundred acres in area, but only about 60 acres contain peat more than 3 feet thick. The 60-acre tract contains peat 5 feet in average thickness and would yield approximately 60,000 short tons of air-dried peat consisting of black nonfibrous plastic remains of sedges, grasses, swamp ferns, and reeds. The living vegetation is composed of sedges, grasses, reeds, cat-tails, and swamp ferns. The following test borings were made:

Thickness of peat in test borings near Antioch, Lake County, Ill.

	Feet.
Hole A, 60 yards from east edge, near railroad station: Black plastic well-decomposed peat, underlain by sand	5
Hole B, 150 yards west of hole A: Black plastic well-decomposed peat, underlain by sand	5

A typical sample (analysis 302, p. 27) was obtained by mixing peat taken at intervals of 2 feet in depth from both test holes. The ash content is 21.74 per cent, the calorific value 7,756 British thermal units, and the nitrogen content 2.85 per cent. The deposit can not be recommended as a source of fuel, but if it were properly

drained the peat might be profitably used for the cultivation of acid-tolerant crops or for an ingredient of commercial fertilizer.

Locality 6.—A marsh about 2½ miles west of Antioch, in secs. 12 and 13, T. 46 N., R. 9 E., contains a deposit approximately 100 acres in area and 6 feet in average thickness, which would yield approximately 120,000 short tons of air-dried peat. The living vegetation consists chiefly of sedges, marsh grass, reeds, and rushes, though pond lilies are numerous along some of the channels. The peat is brown, fibrous, coarse, and spongy, and is composed principally of coarse sedge and grass roots and reeds. Samples were taken along the banks of a large drainage ditch that crosses the marsh, and a representative specimen (see analysis 303, p. 27) was obtained by mixing the material from the different test holes. The ash content is very low (9.12 per cent), but the peat is too fibrous and spongy for fuel. The nitrogen content (2.52 per cent) suggests that the peat might be valuable for agricultural use. Large quantities of moss suitable for stable litter or packing material could readily be obtained at this locality.

Locality 7.—A large marsh north of Grass Lake, about 3½ miles west of Antioch, in secs. 14 and 15, T. 46 N., R. 9 E., contains a deposit 400 acres in area and 5½ feet in average thickness, which would yield approximately 440,000 short tons of air-dried muck. On June 20, 1918, this marsh was flooded by water from Grass Lake and Fox River and was therefore difficult of access. The surface is overgrown by giant sedges and associated reeds and rushes. The muck is black, soft, and plastic, and is underlain by marl. The following test borings were made at points along an east-west line through the center:

Thickness of muck in test borings in marsh north of Grass Lake, Lake County, Ill.

	Feet.
Hole A, 100 yards west of east edge; black well-decomposed plastic muck, underlain by marl	5
Hole B, 100 yards west of hole A; black well-decomposed soft, plastic muck, underlain by marl	5½
Hole C, 200 yards west of hole B; black well-decomposed soft, plastic muck, underlain by marl	5½
Hole D, 100 yards west of hole C; black well-decomposed soft, plastic muck, underlain by marl	5½

A composite sample (analysis 304, p. 27) was obtained by mixing peat taken at intervals of 2 feet in depth from each of the four test holes. The ash content (41.97 per cent) indicates that the material in this deposit is unfit for fuel, but the nitrogen content (2.45 per cent) is relatively high and suggests that the deposit may be valuable for agricultural use. The sedge growth is suitable for the production of packing material.

Locality 8.—A deposit about 1 mile west of Antioch, in secs. 7 and 18, T. 46 N., R. 10 E., which is 120 acres in area and 8 feet in average thickness, would yield about 192,000 short tons of air-dried peat. The peat is black and consists chiefly of the remains of sedges, grasses, swamp ferns, and moss. The living vegetation is composed of sedges and swamp ferns. The following test borings were made at intervals of 100 yards along a line extending from the northeast to the southwest corner of the deposit, as well as at a point 100 yards northwest of the center:

Thickness of peat in test borings in deposit 1 mile west of Antioch, Ill.

	Feet.
Hole A, 100 yards southwest of northeast corner; black, compact, well-decomposed peat, underlain by marl	5
Hole B, 100 yards southwest of hole A; black well-decomposed peat, underlain by marl	7
Hole C, 100 yards southwest of hole B; black well-decomposed peat, underlain by marl	10
Hole D, 100 yards southwest of hole C; black well-decomposed peat, underlain by marl	9
Hole E, 100 yards northwest of center of deposit; black well-decomposed peat, underlain by marl	9

A composite sample (analysis 305, p. 27) was obtained by mixing peat obtained at intervals of 2 feet in depth from each of the test holes. The ash content is 20.61 per cent and the nitrogen 3.18 per cent. The deposit can not be recommended as a source of fuel, but on account of the large percentage of nitrogen it should be valuable for agricultural use.

Locality 9.—A small deposit on the Lynnhurst farm, about 2½ miles east of Lake Villa, in the center of sec. 35, T. 45 N., R. 10 E., is 30 acres in area, 12 feet in average thickness, and would yield approximately 72,000 short tons of air-dried peat. The living vegetation consists chiefly of sedges, swamp ferns, and moss, and the peat is brown, fibrous, and spongy. A test boring made near the center of the deposit gave the following results:

Log of test boring near center of deposit on Lynnhurst farm, Lake Villa, Ill.

	Feet.
Brown fibrous spongy mat, composed of roots of living plants	1
Brown fibrous peat, little decomposed	2
Brown, partly disintegrated peat, firm but fibrous	4
Brown soft, plastic peat, underlain by sand	5

Analysis 306 (p. 27) shows that the peat contains only 10.6 per cent of ash and that the nitrogen content is 2.88 per cent. The deposit could therefore be used for the production of fuel or fertilizer, especially the lower layers.

Locality 10.—A deposit of the meadow type, about 1 mile south of Hainesville, on the Chicago, Milwaukee & St. Paul Railway, in secs. 33 and 34, T. 45 N., R. 10 E., is about 400 acres in area. The vege-

tation consists chiefly of grasses, although bulrushes grow in some of the lower and wetter spots. No peat of economic value was found and hence no samples were taken for analysis. This area could perhaps be used for the cultivation of crops.

LEE COUNTY.

Locality 11.—Several small meadows, about 4 miles southeast of Amboy, each of which is between 20 and 30 acres in area, contain muck, but no peat of economic value was found in this locality.

Locality 12.—Several large meadows or marshes along the Green River valley contain a little peat, but most of the material consists of shallow muck. No samples were taken for analysis.

MASON AND TAZEWELL COUNTIES.

Localities 13 and 14.—A large deposit occupies parts of secs. 15, 16, 21, and 22, T. 23 N., R. 6 W., near Manito. The material in the western and eastern parts of this deposit is different in thickness and quality.

The eastern part of the deposit is 120 acres in area and 5 feet in average thickness and would yield approximately 120,000 short tons of air-dried peat. The living vegetation is composed of grasses and the milkweed, and the peat, which is largely black and plastic, consists of the remains of these plants. The lower layers are so thoroughly decomposed that the plant remains are difficult to identify. Five test borings made along north-south and east-west lines through the center of the deposit gave the following results:

Thickness of peat in test borings in central part of deposit near Manito, Ill.

	Feet.
Hole A, 100 yards east of west edge: Brown, fibrous peat in upper layers to black plastic peat at bottom, underlain by sand	9
Hole B, 100 yards east of hole A: Same kind of peat as that in hole A, underlain by sand	5
Hole C, 100 yards east of hole B: Material of same character as that obtained in hole B	5
Hole D, 100 yards south of north edge: Same kind of peat as that in hole C, underlain by sand	3
Hole E, 100 yards south of hole D: Material of same character as that in hole D	3

According to analysis 313 (p. 27), the ash content of the peat is 26.57 per cent and the nitrogen 2.24 per cent. Although this part of the deposit can not be recommended as a source of fuel, the peat is especially suitable for direct use as a fertilizer or for a nitrogenous ingredient of commercial fertilizers.

The western part of this deposit is about 240 acres in area and 3 feet in average depth and contains the equivalent of about 144,000 short tons of air-dried muck. The living vegetation is similar to

that in the eastern part, and the muck is black and plastic and is underlain by clay and sand. Three test borings gave the following results:

Thickness of peat in test borings in western part of deposit near Manito, Ill.

	Feet.
Hole A, 400 yards east of plant of Weidmer Chemical Co.: Black plastic well-decomposed muck, underlain by sand	2
Hole B, 100 yards south of hole A: Black plastic well-decomposed muck, underlain by clay	3
Hole C, 100 yards south of hole B: Black plastic well-decomposed muck, underlain by sand	3

According to analyses 314, 315, and 316 (p. 27), the muck seems to be well adapted for use as a nitrogenous fertilizer.

WHITESIDE COUNTY.

Locality 15.—Cattail Slough, near Sollers, in Cattail Valley, in secs. 6, 7, 8, 17, 18, 19, 20, 28, 29, 32, and 33, T. 21 N., R. 4 E., contains a deposit several square miles in area, but the part here considered embraces only 1,280 acres near the south end of Cattail Valley, in secs. 28, 29, 32, and 33. (See fig. 3.) The average thickness of the peat in this part of the deposit, which would yield approximately 3,840,000 short tons of air-dried material, is about 15 feet. The living vegetation consists of marsh grasses, sedges, bulrushes, reeds, and cat-tails. The upper layers of peat are brown and fibrous, but the underlying strata are well decomposed and plastic.

Test-borings made along two intersecting lines extending southwest and southeast through the center of the area gave the following results:

Thickness of peat in test borings in Cattail Slough, Whiteside County, Ill.

	Feet.
Hole A, about 150 yards northeast of road along western edge of deposit: Brown fibrous to black plastic decomposed peat, underlain by sand	13
Hole B, 450 yards northeast of hole A: Brown fibrous to black decomposed peat, underlain by sand	15
Hole C, 450 yards northeast of hole B: Brown fibrous peat, underlain by marl containing snail shells	16
Hole D, 450 yards northeast of hole C: Brown fibrous to black decomposed peat, underlain by marl containing snail shells	15
Hole E, 450 yards southeast of hole C, along a line at right angles to holes A, B, C, and D: Brown fibrous peat, rather woody near bottom, underlain by sand	15
Hole F, 450 yards northwest of hole C: Brown fibrous to black, partly disintegrated peat, underlain by marl and sand	16

	Feet.
Hole G, 450 yards northwest of hole F: Brown fibrous to black, partly disintegrated peat, underlain by sand	15
Hole H, 450 yards northwest of hole G: Brown fibrous to black, partly disintegrated peat, underlain by sand	16
Hole I, 450 yards northwest of hole H: Brown fibrous to black, well-decomposed peat, underlain by sand and marl	14
Hole J, 450 yards northwest of hole I: Brown fibrous to black, well-decomposed peat, underlain by marl and sand	13

The quality of the peat from holes A, B, C, and D is shown by analysis 307; from holes E, F, G, and H by analysis 308, and from holes I and J by analysis 309. (See p. 27.) A comparison of these analyses shows that the peat contains relatively little ash, is high in calorific value, and therefore might be advantageously used for fuel. The high average nitrogen content of the peat (3.06 per cent) also indicates that it is suitable for fertilizer. This is one of the most valuable peat deposits in Illinois. Much of the area has already been drained and is used for farming. The Clinton branch of the Chicago, Burlington & Quincy Railroad crosses the deposit, and when trains are passing the surface quakes violently.

FIGURE C.—Map of Cattail Valley, Whiteside County, Ill.

Locality 16.—A deposit in the upper Cattail Valley, including parts of secs. 6, 7, 8, 17, and 18, T. 21 N., R. 4 E., comprises about 1,300 acres of peat 12 feet in average depth and would yield approximately 3,120,000 short tons of air-dried peat. The living vegetation consists chiefly of cat-tails, bulrushes, sedges, grasses, and reeds. The peat is brown and fibrous near the surface, but the underlying strata are well decomposed. Analysis 310 (p. 27) represents the composition of peat taken at several points along the sides of a large drainage ditch that crosses the deposit. It shows the peat to be similar in composition and quality to that which occurs in the southern part of Cattail Slough. The ash content is 16.63 per cent, the calorific value is 8,464 British thermal units, and the nitrogen content is 2.52 per cent. Analyses 311 and 312 (p. 27) show the composition of the muck in this locality.

INDIANA.

GENERAL FEATURES.

The peat deposits of Indiana are confined to the glaciated region in the northern part of the State. The greater part of the peat occupies the basins of ancient glacial lakes, but a few deposits were formed in depressions between sand dunes and in marshes along meandering streams. The following counties contain most of the peat in Indiana: Allen, Dekalb, Elkhart, Fulton, Jasper, Kosciusko, Lagrange, Lake, Laporte, Marshall, Newton, Noble, Porter, Pulaski, St. Joseph, Starke, Steuben, Wabash, and Whitley. Areas of peat in these counties are shown on maps accompanying a report[29] published by the Indiana Department of Geology and Natural Resources. Bogs and marshes containing sphagnum and grass-sedge peat are the predominant types. The deposits range from 5 to 2,500 acres in area and from 1 to 25 feet in thickness, but most of them are less than 100 acres in area and less than 6 feet in depth. The upper layers are generally brown and fibrous and the lower black, well-decomposed, and plastic. A large quantity of the peat is underlain by marl of good quality.

The peat deposits of Indiana are estimated to be capable of yielding 51,000,000 short tons of air-dried peat. This estimate, which is based upon Taylor's report,[30] supplemented by data collected by R. G. Butler, includes only peat and muck deposits that are 20 acres or more in area and not less than 2½ feet deep, except that if small deposits occur in the same general locality they have been considered as a unit. The large, shallow deposits are included because they offer great agricultural possibilities. Probably not more than one-fourth of the peat in this estimate, or about 13,000,000 tons, is suitable for commercial use other than as crop soil. The deep impure peat can not be used for fuel, but much of it is high in nitrogen and may be valuable for fertilizer.

Quantity of peat and muck in Indiana, by counties, estimated as air-dried material (short tons).

Allen	500,000
Dekalb	1,612,000
Elkhart	3,500,000
Fulton	1,500,000
Jasper	2,250,000
Kosciusko	6,000,000
Lagrange	2,000,000
Lake	3,350,000
Laporte	1,660,000

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[29] Taylor A. E., The peat deposits of northern Indiana: Indiana Dept. Geology and Nat. Res., Thirty-first Ann. Rept., pp. 73-285, 1906.

[30] Taylor, A. E., op. cit.

Marshall	3,595,000
Miami	50,000
Newton	240,000
Noble	3,260,000
Porter	1,130,000
Pulaski	1,652,000
St. Joseph	8,388,000
Starke	4,333,000
Steuben	4,000,000
Wabash	200,000
Whitley	1,780,000
	51,000,000

Many peat deposits in Indiana have been described in detail by Taylor in the Thirty-first Annual Report of the Indiana Department of Geology and Natural Resources. The following additional deposits were examined by the United States Geological Survey:

ALLEN COUNTY.

Locality 1.—A deposit in the SW. ¼ sec. 25 and the SE. ¼ sec. 24, Aboite Township, about 8 miles west of Fort Wayne, which is owned by the Virginia-Carolina Chemical Co., of Richmond, Va., is about 100 acres in area. The peat is brown and fibrous and is composed chiefly of the remains of grasses and sedges. The deposit is 4 feet in average depth and should yield approximately 80,000 tons of air-dried peat. The dominant living vegetation consists of cat-tails, giant sedges, and swamp willows. Samples were taken from eight test borings made at intervals of 100 yards along a north-south line through the center of the deposit. Two typical samples (analyses 339 and 340, p. 27) were obtained by mixing peat from the different test holes. A comparison of these analyses shows the peat to be uniform in composition. The average ash content is about 18.4 per cent and the average nitrogen content about 3.3 per cent. Although the ash content is not high, the calorific value is rather low and the peat is too fibrous for good fuel. The Virginia-Carolina Chemical Co. operated a fertilizer plant at this deposit until its buildings were destroyed by fire in April, 1918. The machinery was saved, and the company reports that the plant will resume operations. Analysis 338 (p. 27) shows the quality of the dried peat from this deposit as used commercially for fertilizer.

DEKALB COUNTY.

Locality 2.—A deposit in the NE. ¼ sec. 9, Butler Township, is the site of the peat-moss plant of Baker & Co., which is no longer in operation. The deposit is 40 acres in area and 12 feet in average

thickness and should yield approximately 96,000 short tons of air-dried peat. The living vegetation consists chiefly of grasses and the huckleberry. The peat is dark brown and rather friable near the surface; the underlying peat is plastic. Four test borings were made along a line from east to west across the deposit and a representative sample (analysis 343, p. 27) was obtained by mixing peat taken from each of these test holes. The ash content is 5.34 per cent, and the calorific value 8,757 British thermal units. The peat therefore appears to be suitable for fuel.

Locality 3.—A deposit in the NW. ¼ sec. 33 and the NE. ¼ sec. 32, Richland Township, which is about 30 acres in area and 17 feet in average depth, should yield approximately 102,000 short tons of air-dried peat. The peat ranges in color from light to dark brown and in texture from fibrous to plastic. It is composed chiefly of the remains of grasses and sedges, and plants of this kind are still the predominant living vegetation of the area. Peat is still in process of formation on this deposit. Analysis 341 (p. 27) shows the quality of the peat of this deposit. The ash content is 12.08 per cent, the nitrogen content 3 per cent, and the calorific value 8,412 British thermal units. The deposit, though rather small in area, seems to contain peat suitable for either fuel or fertilizer.

ELKHART COUNTY.

Locality 4.—A deposit in the SE. ¼ sec. 10, T. 36 N., R. 6 E., is about 30 acres in area and 4 feet in average depth. It is estimated to contain the equivalent of 24,000 tons of air-dried peat. The peat is dark brown and well decomposed and consists chiefly of the remains of mosses, sedges, and grasses. Four test borings were made and a representative sample (analysis 332, p. 27) was obtained by mixing peat taken from each of these holes. The ash content (25.03 per cent) is too high for the peat to be used as fuel. However, the nitrogen content (2.84 per cent) is relatively high, and the deposit is therefore valuable as a source of humus or nitrogen or as a crop soil.

Locality 5.—A large deposit in the E. ½ sec. 27, the SE. ¼ sec. 26, the center of sec. 35, and the SE. ¼ sec. 36, T. 35 N., R. 5 E., contains an area of about 700 acres, and the average depth of the peat is about 18 feet. The deposit should therefore yield approximately 2,500,000 short tons of air-dried peat. The peat, which is composed chiefly of the remains of moss and grass, is brown and fibrous and contains considerable woody material. The deposit is distinctly stratified and is underlain by sand. The living vegetation consists largely of grasses. However, scattered groves of maple, willow, and poplar are found in places in the area. Four test borings were made at intervals of 400 yards along a northwest-southeast line through the center of the deposit, and a typical sample (analysis 333, p. 27)

was obtained by mixing peat taken at intervals of 2 feet in depth in each of these test holes. The peat appears to be of good quality for fuel or for a nitrogenous ingredient of commercial fertilizer.

Locality 6.—A deposit in the N. ½ sec. 13 and in sec. 14, Osolo Township, and the NW. ¼ sec. 18, Washington Township, is about 500 acres in area. The peat is dark brown and fibrous and is composed chiefly of the remains of mosses, grasses, and sedges. Some woody matter was also found. Four test borings were made at intervals of 400 yards along an east-west line through the center of the deposit. About 350 acres contains peat 12 feet in average depth, and the peat in the remaining 150 acres is about 4 feet in average thickness. The deposit should yield approximately 960,000 short tons of air-dried peat. A representative specimen (see analysis 337, p. 27) was obtained by mixing peat taken at intervals of 2 feet in depth in each of the test holes. The ash content (10.99 per cent) is relatively low and the fuel value (8,566 British thermal units) comparatively high. The peat is chemically suitable for fuel, but it is probably too fibrous to be utilized for the manufacture of machine peat. A noteworthy feature of the analysis is the high nitrogen content (3.29 per cent). The peat seems to be well adapted for making fertilizer.

FULTON COUNTY.

Locality 7.—A deposit in sec. 20, T. 30 N., R 5 E., about 2 miles east of Akron, occupies an area of about 300 acres. The peat occurs in pockets and hence is not uniform in depth. The average thickness is probably about 10 feet, so that the deposit should yield approximately 600,000 short tons of air-dried peat. The surface is well drained, although the general elevation of the deposit is not far above the water level in several near-by lakes. The living vegetation is composed chiefly of grasses and of aspen, poplar, and willow trees. Many fallen logs lie on the surface. The peat is brown and fibrous and contains much woody matter. The surface layer is unusually fibrous and might be advantageously utilized for packing material or stable litter. Analysis 328 (p. 27) shows the quality of the peat. The ash content is 10.99 per cent and the fuel value is 8,888 British thermal units. Although the analysis indicates that the peat is suitable for fuel, it is so fibrous that there is doubt whether the deposit could be used in the manufacture of machine fuel. The high nitrogen content (2.98 per cent) indicates that the peat may be of agricultural value.

Locality 8.—A bog in the SE. ¼ sec. 21 and the NE. ¼ sec. 28, T. 30 N., R. 5 E., about 3 miles east of Akron, is about 38 acres in area and 8 feet in average thickness and is estimated to be capable of yielding 600,000 short tons of air-dried peat. The peat, which is composed chiefly of the remains of mosses, grasses, and shrubs, is brown and

fibrous to plastic and contains some woody matter. The living vegetation consists largely of the cranberry, tamarack trees, and swamp ferns. A composite sample (analysis 329, p. 27) was obtained by mixing peat from various test holes. The ash content is only 8.82 per cent, and the nitrogen content is above the average. The peat therefore seems to be of good quality for fuel or fertilizer.

JASPER COUNTY.

Locality 9.—A large deposit occupies parts of secs. 7, 8, 12, 13, 14, 16, 17, and 18, Tps. 30 and 31 N., R. 5 W. The area sampled consists of about 450 acres in sec. 18. The average thickness of the deposit in sec. 18 is about 10 feet and the quantity of air-dried peat available is about 900,000 short tons. The peat is largely dark brown and fibrous to plastic. Greenish pond peat underlain by clay and sand was found near the bottom. The peat is composed chiefly of the remains of sedges and of grasses. The dominant living vegetation in sec. 18 is grasses and sedges. A representative sample (analysis 321, p. 27) was obtained by mixing peat taken at intervals of 2 feet in depth from each of the test holes put down along an east-west line through the center of sec. 18. The peat contains 3.34 per cent nitrogen and 16.15 per cent of ash, and the calorific value is 8,477 British thermal units. Although the deposit is not easily accessible, it would supply a large quantity of peat suitable for agricultural uses or for fuel.

KOSCIUSKO COUNTY.

Locality 10.—A large bog occupies parts of secs. 12, 13, 14, 23, 24, 25, and 26, Etna Township, and parts of secs. 18, 19, 30, and 31, Prairie Township. The area of the bog is about 2,500 acres, and the average thickness of the peat is 10 feet. The deposit, according to estimate, would yield 5,000,000 short tons of air-dried peat. The living vegetation consists chiefly of grasses, sedges, sphagnum, swamp ferns, and tamarack. Many fallen tamarack logs and stumps are found beneath the peat, as well as on the surface. The peat is brown and grades from fibrous material in the upper layers to plastic peat at the bottom. Test borings were made along an east-west line across the centers of sec. 13, Etna Township, and sec. 18, Prairie Township. Typical samples (analyses 330 and 331, p. 27) were obtained by mixing peat taken at intervals of 2 feet in depth from each of the test holes. The peat is uniform in quality. The nitrogen content is about 2.5 per cent and the ash content about 9 per cent. The average calorific value of the two samples is 8,497 British thermal units. This is one of the largest peat bogs in Indiana and contains a large quantity of peat suitable for either fuel or fertilizer. The deposit adjoins the tracks of the Pennsylvania Railroad and is therefore readily accessible.

MARSHALL COUNTY.

Locality 11.—A bog that occupies an old lake basin in secs. 7, 8, and 18, German Township, is about 300 acres in area, 10 feet in average thickness, and, according to estimate, would yield 600,000 short tons of air-dried peat. The peat, which is composed chiefly of the remains of sphagnum moss and grasses, is light to dark brown, fibrous near the surface, and plastic at the bottom. The living vegetation consists chiefly of grasses, sedges, sphagnum, the huckleberry, and poplar, and maple trees. A composite sample (analysis 325, p. 27) was obtained by mixing peat taken at intervals of 2 feet in depth from numerous test borings. The deposit could easily be drained and worked to a depth of 6 or 7 feet, and the peat appears to be of good quality for either fuel or fertilizer.

Locality 12.—A small bog in the NE. ¼ sec. 10, near Tyner, which is 20 acres in area and contains a deposit of peat 15 feet in average thickness, should yield approximately 60,000 short tons of air-dried peat. The peat is dark-brown and is composed largely of the remains of sphagnum moss. It is fibrous and mossy except in the lower layers. The living vegetation consists chiefly of the blackberry, grasses, and trees. The peat is underlain by clay, marl, and sand. A representative sample (analysis 326, p. 27) was obtained by mixing peat from several test holes put down along an east-west line through the center. The peat seems to be of good quality for fuel. Analysis 327 (p. 27) shows the quality of a sample of air-dried hand-cut peat from this bog. The ash content of this sample is 8.17 per cent and the calorific value 9,299 British thermal units. Hand-cut peat from this bog has been used for fuel by C. F. Brown, the owner.

NOBLE COUNTY.

Locality 13.—A bog in the NE. ¼ sec. 29, and the NW. ¼ sec. 28, Wayne Township, is about 100 acres in area and contains peat 3 feet in average thickness. The peat is brown and rather fibrous and is composed chiefly of the remains of mosses and sedges. The living vegetation consists of moss, willow, sumac, and tamarack. A typical sample (analysis 342, p. 27) was obtained by mixing peat taken from several test holes. The peat appears to be of good quality for fuel or fertilizer. The deposit, however, is so shallow that it can not be recommended as a favorable site for a peat plant.

PULASKI COUNTY.

Locality 14.—A large deposit that occupies secs. 7, 8, and 9 and parts of 16 and 17, Rich Grove Township, is about 1,000 acres in area, and the peat is 4 feet in average depth. The deposit should yield approximately 800,000 short tons of air-dried peat. The peat, which is composed of the remains of grasses and sedges, is dark brown near

the top and yellow to green near the bottom and is underlain by green and blue clay. The living vegetation consists chiefly of grasses and sedges. The deposit has been drained, and much of it is under cultivation, corn being the principal crop grown. A typical sample (analysis 322, p. 27) was obtained by mixing peat taken from numerous test holes. The nitrogen content is 2.91 per cent. The area is probably of more value for cultivation than as a source of peat fuel.

ST. JOSEPH COUNTY.

Locality 15.—A deposit in the NE. ¼ sec. 12 and the E. ½ sec. 1, Warren Township, is 250 acres in area, and the peat, which occurs in pockets, is about 6 feet in average depth. It is estimated that this deposit should yield 240,000 short tons of air-dried peat. The peat is brown to black and fibrous and is composed chiefly of sedges, grasses, and moss. The living vegetation consists chiefly of marsh grass. A composite sample (analysis 324, p. 27) was obtained by mixing peat taken from several test holes. The peat is low in ash, the nitrogen content is 2.86 per cent, and the calorific value is 8,331 British thermal units. An odor of hydrogen sulphide was noted while making the test borings.

Locality 15a.—A deposit in secs. 18, 19, and 20, T. 37 N., Olive Township, which is well drained, was formerly the northern part of the Kankakee Valley marsh. The deposit consists of muck, which is shallow and contains a large proportion of inorganic mineral matter. Most of the deposit is under cultivation and is used extensively for growing mint. As the muck is of no value for fuel or as an ingredient of commercial fertilizer, no samples were taken for analysis.

Locality 15b.—A deposit of muck in secs. 15 and 16, Portage Township, is similar in depth and quality to that in locality 15a. It is used for the cultivation of various crops and is more valuable as crop soil than as a source of fuel. No samples were taken for analysis.

Locality 16.—A bog that occupies parts of secs. 28, 33, and 34, T. 36 N., R. 2 E., and parts of secs. 2, 3, 11, 12, 13, and 14, T. 35 N., R. 2 E., is one of the largest peat deposits in Indiana. The plant of the St. Joseph Humus Co., of Lakeville, is in the SE. ¼ sec. 34. The peat is brown and fibrous to plastic and consists largely of the remains of grasses, sedges, sphagnum, and tamarack. The living vegetation consists largely of the same plants. The average thickness is about 6½ feet. Analyses 334, 335, and 336 (p. 27) show the quality of the raw peat from this deposit. The peat contains a large quantity of ash, but the nitrogen content ranges from 2.20 to 2.92 per cent. The equipment at the plant of the St. Joseph Humus Co. consists of excavating, loading, and grinding machinery

and one large rotary drier. The product of this plant is used as a nitrogenous ingredient of commercial fertilizers.

STARKE COUNTY.

Locality 17.—A deposit in the SE. ¼ sec. 21, the SW. ¼ sec. 22, the W. ½ sec. 27, sec. 28, the NE. ¼ sec. 33, and the NW. ¼ sec. 34, Wayne Township, is about 300 acres in area, and the peat is 8 feet in average thickness. The deposit should yield approximately 480,000 short tons of air-dried peat. The living vegetation consists chiefly of sedges, grasses, and the swamp willow. The peat, which is made up chiefly of the remains of sedges and grasses, is dark brown to light brown, fibrous near the top, soft and decomposed at the bottom, and is underlain by sand. Test borings were made at intervals of 450 yards along a northwest-southeast line across the deposit. Two composite samples (analyses 318 and 319, p. 27) were obtained by mixing peat taken at intervals of 2 feet in depth from each of the test holes. The nitrogen content is high, and the peat seems to be of good quality for fuel or for a nitrogenous ingredient of commercial fertilizers.

Locality 18.—Deposits in secs. 31, 32, and 33, T. 32 N., R. 3 W., Wayne Township, are about 600 acres in area and 6 feet in average thickness and should yield approximately 720,000 short tons of air-dried peat. The living vegetation consists chiefly of sedges and grasses. Large quantities of marsh grass are produced from this deposit and used for packing material. The peat, which is brown and fibrous, is composed chiefly of the remains of grasses and sedges. A typical sample (analysis 320) was obtained by mixing peat taken at intervals along a large drainage ditch that crosses the marsh. Although the ash content is only 12.1 per cent, the peat is fibrous and is therefore not well adapted for machine fuel. The high nitrogen content (3.26 per cent) indicates that the peat may be of value as a nitrogenous ingredient of commercial fertilizers. If properly drained a large part of the area might be utilized for the cultivation of crops.

Locality 19.—A deposit in the SW. ¼ sec. 10, T. 32 N., R. 3 W., Wayne Township, is about 70 acres in area and 7 feet in average thickness; it should yield approximately 98,000 short tons of air-dried peat. The peat, which is composed chiefly of the remains of moss, sedges, and grasses, is brown and fibrous near the top but soft and plastic at the bottom. The living vegetation includes a thick growth of grasses, sedges, and the cranberry. A typical sample (analysis 323, p. 27) was obtained by mixing peat taken at intervals of 2 feet in depth from several test holes put down along a north-south line through the center of the deposit. The peat is uniform in texture and is physically suitable for machine-peat fuel. The ash content is 14.04 per cent.

STEUBEN COUNTY.

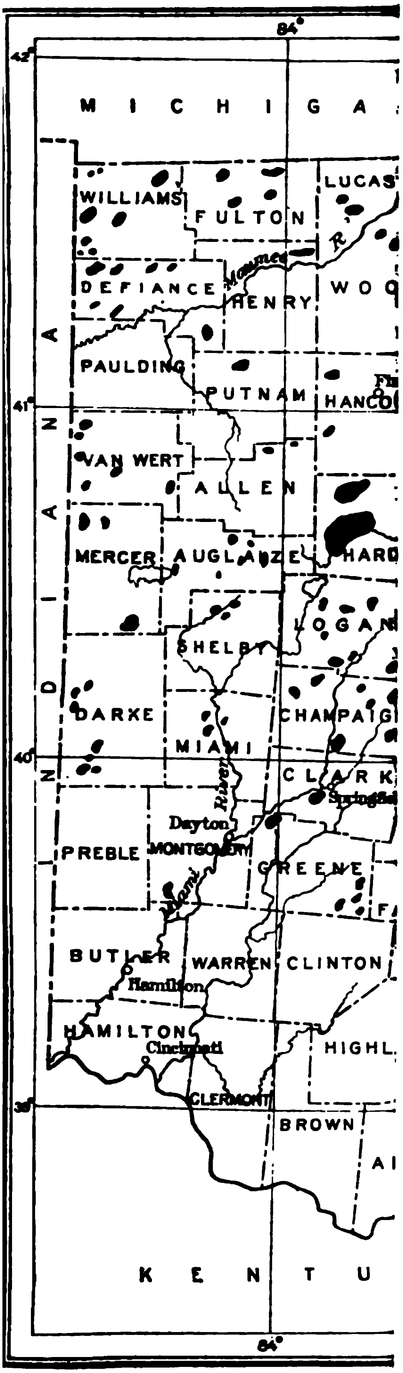
Locality 20.—A large bog that occupies parts of secs. 15, 16, 21, 22, and 28, Steuben Township, contains a deposit about 600 acres in area and 14 feet in average thickness, which should yield approximately 1,680,000 short tons of air-dried peat. The living vegetation consists chiefly of sedges, grasses, moss, and small tamarack trees. The peat is light brown and fibrous near the surface, but the underlying layers are dark brown, soft, plastic, and well disintegrated and are composed chiefly of the remains of sedges, grasses, and moss. Test borings were made at intervals of 100 yards along a north-south line extending through the center of the deposit. Analysis 344 (p. 27) shows the peat to be of excellent quality for fuel or fertilizer. The ash content is 12.44 per cent, the percentage of nitrogen 3.66, and the calorific value 8,782 British thermal units. There are many other peat deposits in this locality, but this one is among the best in Steuben County and would be a good site for a peat plant.

Locality 21.—A bog that surrounds Little Center Lake, near the town of Angola, Pleasant Township, contains a deposit about 40 acres in area and 4 feet in average thickness. The peat is underlain by clay and sand. The living vegetation consists chiefly of grasses, sedges, moss, and tamarack. The peat is brown and fibrous and contains many roots of trees and shrubs. A typical sample (analysis 345, p. 27) was obtained by mixing peat taken from several test holes put down at different places throughout the deposit. The peat appears to be of good quality for fuel or fertilizer, but the deposit is probably too small for the production of peat on a commercial scale.

Locality 22.—A bog that surrounds Big Center Lake, occupying parts of secs. 21 and 22, Pleasant Township, contains a deposit about 150 acres in area and 10 feet in average thickness, which should yield approximately 300,000 short tons of air-dried peat. The peat, which is made up chiefly of the remains of sphagnum moss, is brown and fibrous near the top of the deposit but soft and well decomposed at the bottom. The living vegetation consists chiefly of sphagnum and tamarack. Analysis 346 (p. 27) shows the peat to be apparently of good quality for fuel or fertilizer. The calorific value is 8,922 British thermal units and the nitrogen content is 3.76 per cent.

OHIO.

The principal peat deposits in Ohio occur in the region bordering Lake Erie and in the northwestern part of the State. (See Pl. X.) The following counties contain the largest deposits: Ashland, Ashtabula, Auglaize, Crawford, Defiance, Geauga, Hardin, Huron, Logan, Mahoning, Mercer, Portage, Seneca, Stark, Summit, Trumbull, Van Wert, Wayne, Williams, and Wyandot. As in other States in the


84°
42°
41°
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39°
MICHIGA
INDIANA
WILLIAMS
FULTON
LUCAS
Maumee R.
DEFIANCE
HENRY
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PAULDING
PUTNAM
HANCO
VAN WERT
ALLEN
MERCER
AUGLAIZE
HARD
SHELBY
LOGAN
DARKE
MIAMI
CHAMPAIG
CLARK
Springfiel
Dayton
Miami River
PREBLE
MONTGOMERY
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northern region, most of the peat deposits of Ohio were formed in glacial lakes and ponds and in other wet places in depression of glacial origin. In some places peat entirely surrounds small ponds, the remnants of larger glacial lakes that have been gradually filled by vegetation. In other places peat has accumulated on relatively flat, undrained land. Dachnowski[31] states that the following varieties of peat occur in Ohio: Coarse, fibrous, spongy, light-brown peat in the upper layers of basin deposits; compact, well decomposed, plastic dark-brown to black peat in the lower layers of basin deposits; fibrous, firm brown peat in built-up deposits.

Most of the peat in Ohio was formed chiefly by the decay of sphagnum, grasses, and sedges and is therefore largely fibrous near the surface. Many of the deposits are underlain by marl. The area of peat and muck in Ohio is estimated to be about 150,000 acres. Perhaps one-third of this area, or 50,000 acres, contains workable peat. The thickness of the peat ranges from 1 to 20 feet, and the average is about 5 feet. If these figures are correct the peat deposits of Ohio should yield approximately 50,000,000 short tons of air-dried peat. Probably 25,000,000 tons is suitable for fuel or fertilizer.

The following table[32] briefly describes the principal peat deposits in Ohio:

Location, area, depth, and character of peat deposits in Ohio.

Deposit No.	County.	Township.	Section.	Area (acres).	Depth (feet).	Character of peat and vegetation.
1	Ashland	Lake	23	60	17	Reddish brown, fibrous. Cranberry-sphagnum meadow.
2	Ashtabula	Orwell		1,000	5	Dark brown, partly fibrous, woody and well decayed. Tamarack, maple, alder.
3	Champaign	Urbana	31–32	600	4	Dark brown, slightly fibrous, well decayed. Cedar.
4	Columbiana	Center	7–8	200	6	Dark brown, well decayed, partly fibrous. Moss and tamarack.
5	Crawford	Auburn		500	5	Dark brown, partly fibrous. Under cultivation.
6	do.	Cranberry	24–26	300	6	Same.
7	Cuyahoga	Solon		300–400	10	Brown, well decomposed, partly fibrous. Sedges and others.
8	Darke	Butler	7, 18	200(?)	2	Dark brown, well decayed. Under cultivation.
9	do.	Harrison	13		4	Same, slightly fibrous.
10	Defiance	Milford	9–11	100	15	Dark brown, well decayed, slightly fibrous. Tamarack.
11	do.	do.		5	15	Brown, fibrous, partly structureless. Under cultivation.
12	Fairfield	Amanda	26		12	Dark brown, well decayed, partly fibrous. Under cultivation.
13	Geauga	Bainbridge		70	19	Brown, partly fibrous, well decayed with several bog associations.
14	do.	Burton		100	17	Same, slightly woody.
15	Greene	Bath	1–2	100(?)	7	Dark brown, partly fibrous. Under cultivation.
16	Hancock	Big Lick	20–34	2,000	3	Dark brown, partly structureless, somewhat woody. Heath bog.
17	Hardin	Marion	27	16,000	5	Dark brown, partly fibrous, well decomposed. Under cultivation.

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[31] Dachnowski, Alfred, The peat deposits of Ohio: Ohio Geol. Survey Bull. 16, 4th ser., p. 18, 1912.

[32] Idem, pp. 363–365.

Location, area, depth, and character of peat deposits in Ohio—Continued.

Deposit No.	County.	Township.	Section.	Area (acres).	Depth (feet).	Character of peat and vegetation.
18	Hardin	Marion	27		5	Dark brown, well decomposed. Marl.
19	Holmes	Washington	26	2	19	Brown, fibrous, well decomposed below. Cranberry-sphagnum.
20	Huron	Richmond		5,500	15	Dark brown, partly well decomposed. Bog meadow and shrubs.
21	do	New Haven		3,500	9	Dark brown, well decomposed. Under cultivation.
22	Licking	Licking		4,000	30	Dark brown to black, partly fibrous.
23	do	do			20	Dark brown, well decomposed, partly fibrous. Maple-alder thicket.
24	do	do			30	Brown, coarsely fibrous. Cranberry-sphagnum meadow.
25	Mahoning	Beaver	24-36	500	16	Dark brown, well decomposed, partly fibrous. Tamarack.
26	Medina	Harrisville		2,000	5	Dark brown, partly fibrous. Under cultivation.
27	do	Westfield			8	Fibrous, partly well decomposed. Sterile soil.
28	Mercer	Granville		1,000	7	Dark brown, structureless, slightly fibrous. Under cultivation.
29	do	do			4	Same.
30	do	do	35		1-2	Same.
31	Montgomery	German	18		4	Dark brown, well decomposed. Fossil peat.
32	Portage	Atwater		400	3	Dark brown, slightly fibrous. Tamarack, maple.
33	do	Brimfield	20	200	18	Dark brown, partly fibrous and woody. Maple, ash, elm.
34	do	do		2	9	Brown, fibrous. Cranberry-sphagnum meadow.
35	do	Franklin		30	10-15	Dark brown, well decomposed. Tamarack muskeg.
36	do	Mantua		2,000	8	Dark brown, well decomposed, partly silty. Maple, ash, elm.
37	do	Nelson			4	Nearly black and silty.
38	do	Ravenna		100(?)	17	Brown, fibrous, partly well decomposed. Several associations.
39	Seneca	Big Spring	32	3,000(?)	8	Dark brown, almost structureless. Partly under cultivation.
40	Shelby	Van Buren	14		12	Same.
41	Stark	Canton	6-7	100(?)	19	Brown, fibrous, partly well decomposed. Under cultivation.
42	do	do			5	Same. Tamarack.
43	do	do			5	Same, partly under cultivation.
44	Summit	Copley		3,000	14	Dark brown, moderately fibrous. Partly under cultivation.
45	do	Portage			17	Same. Tamarack.
46	do	Hudson		2,500	18	Dark brown, well decomposed. Maple, ash, elm.
47	Trumbull	Greene		1,500	5	Dark brown, fibrous, partly well decomposed. Tamarack.
48	Wayne	Baughman		300(?)	11	Brown, fibrous, partly structureless. Under cultivation.
49	do	do			11	Reddish brown, fibrous. Under cultivation.
50	do	do			11	Nearly black, well decomposed. Under cultivation.
51	do	do	1-12	400	12	Brown, moderately fibrous. Tamarack.
52	do	do			5	Dark brown, well decomposed. Partly under cultivation.
53	Williams	Florence	30	300	5	Brown, partly fibrous. Tamarack.
54	do	do			16	Same, but well decomposed.
55	do	Bridgewater	14-15		4	Same. Tamarack bog.
56	do	Superior		200	15	Dark brown, moderately fibrous. Under cultivation.
57	do	Madison		40	9	Brown, fibrous, partly well decomposed. Tamarack.
58	Wyandot	Crawford		3,000	12	Dark brown, well decomposed, somewhat woody. Under cultivation.
59	do	do		3,000	14	Same. Heath meadow.
60	do	do		3,000	14	Same. Under cultivation.
61	do	Crane		200	8	Dark brown, well decomposed. Under cultivation.

Detailed information concerning the distribution and properties of Ohio peats may be obtained by consulting Bulletin 16 of the Ohio Geological Survey. Analyses of peat from Ohio are given on page 48.

PENNSYLVANIA.

Most of the peat deposits in Pennsylvania occupy glacial basins in the northern part of the State. In northeastern Pennsylvania, notably in Monroe, Pike, Sullivan, and adjoining counties, many of the glacial lakes contain small quantities of peat. Ganoga Lake, in Sullivan County, and the lakes in the Pocono district, in Monroe County, are typical of the peat-forming basins of Pennsylvania. There are also some vegetal accumulations in marshes adjoining streams, but this material contains so much silt that it is of little value for fuel. The quantity of peat in Pennsylvania suitable for fuel or fertilizer is probably not more than 1,000,000 short tons of the air-dried material.

COLUMBIA COUNTY.

Locality 1.—The eastern part of a deposit on the north side of Susquehanna River, about one-fourth of a mile west of the railroad station at Espy, contains about 100 acres of peat whose average thickness is 6 feet. This deposit is long and narrow and contains many patches of dry land. It should yield approximately 120,000 short tons of air-dried peat. The original vegetation, in which deciduous trees predominated, has been removed. The present flora consists chiefly of grasses, sedges, shrubs, and weeds. That the deposit is of filled-basin origin is shown by the marl that underlies it. The upper layers consist of built-up peat. A test hole made near the drying plant of the Espy Humus Fertilizer Co., which is producing peat fertilizer, gave the following results:

Log of test hole near drying plant of Espy Humus Fertilizer Co., Espy, Pa.

	Feet.
Black fibrous peat	1½
Chocolate-brown to reddish-brown fibrous peat	1½
Chocolate-brown to reddish-brown well-decomposed plastic peat	3
	6

The chemical composition of this peat is shown in the table of analyses (p. 49). The peat from this deposit is excavated by hand, loaded on small tramcars, and hauled by a gasoline motor to the drying plant. The peat is then run through a rotary drier and loaded on railroad cars. As shipped from the plant the peat contains about 10 per cent of moisture and is sold for its nitrogen content.

Locality 2.—Locality 2 includes the western part of the deposit on the north side of Susquehanna River about one-half mile west of the railroad station at Espy. The peat in this locality is separated from that in locality 1 by an intervening area that contains no peat. The deposit ranges from 3 to 10 feet in depth and is underlain by marl about 5 feet deep. Locality 2 is about 60 acres in area and should yield approximately 96,000 short tons of air-dried peat. The

vegetation is similar to that at locality 1, and the deposit is quite similar in character. A large area has been cleared. A test hole in the center of this deposit, where peat is being excavated for sale as fertilizer, gave the following results:

Log of test hole in center of deposit of Espy Humus Fertilizer Co., Espy, Pa.

	Feet.
Black fibrous peat	1½
Brown fibrous peat, containing roots and stems of grasses and sedges	1½
Brown well-decomposed, soft, plastic peat	4
Brown soft, plastic peat, containing marl	1
Marl	5
	13

The chemical composition of this peat is shown in the table of analyses (p. 49). It appears to be suitable for fertilizer, but it contains too much ash for use as fuel.

CRAWFORD COUNTY.

Probably the largest peat deposit in Pennsylvania is in Pymatuning Swamp, western Crawford County.[23] This swamp is nearly 25 miles long, but peat is not found throughout its area. According to Jennings[24] this deposit was originally a sphagnum-tamarack bog, but when the tamarack was cut the sphagnum disappeared, and the area was converted into an alder swamp. Two small patches of tamarack yet stand near Hartstown.

PHILADELPHIA COUNTY.

Locality 3.—A large area surrounded by the Delaware and Schuylkill rivers and Darby Creek, near Hog Island, about 6 miles from the center of the city of Philadelphia, which has been drained and which is largely used for farming and for housing, was carefully examined and numerous test borings were made, but no peat was found in commercial quantities. Most of the surface is covered to a depth of about 1 foot by a mat of fibrous plant remains, consisting of roots and stems of marsh grasses, sedges, weeds, and shrubs. This mat of plant remains is underlain by clayey soil. The area does not contain peat or muck of value for fertilizer.

OTHER COUNTIES.

Peat is found in the following localities in addition to those already discussed: Marsh near Quakertown, Bucks County; Bear Meadows, Center County; Conneaut Marsh, Crawford County; Cranberry Pond and Presque Isle, Erie County; Log Tavern Ponds, Pike County; and Crane and Tamarack swamps, Wyoming County.

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[23] Hice, R. R., written communication, 1918.

[24] Jennings, O. E., written communication.

NEW YORK.

GENERAL FEATURES.

The peat deposits of New York, though numerous and widely distributed, may be in general assigned to three divisions—the northern, the west-central, and the southern—and the predominant deposits in each division show differences in manner of formation and in the quality of the peat. According to their manner of formation they may be classified in three groups—filled-basin deposits, built-up deposits, and composite areas. The built-up deposits may be subdivided into fresh-water deposits and salt-marsh deposits.

The peat deposits of northern New York, which includes the Adirondack region, are largely of filled-basin origin and, though numerous and widely distributed, are relatively small. The peat in many places is of great depth, and the upper layers consist chiefly of the remains of sphagnum moss. Many of these deposits are too remote from transportation facilities to be of present economic value. A few built-up deposits and composite areas also occur in this region.

The peat deposits of central and western New York occur in marshes and swamps and are largely of the built-up type. Many of the largest peat areas in the State are in this region, notably the Cicero and Oak Orchard swamps and Montezuma Marsh. Small filled-basin deposits and composite areas, some of which are underlain by marl, also occur in this region.

Peat deposits that may be both fresh-water and salt-marsh deposits occur in southern New York, which includes Long Island. The "drowned lands" of the Wallkill River Valley contain the largest area of peat in the State—a built-up deposit of fresh-water origin—which covers more than 17,000 acres, and the peat in some places is 25 feet deep. The total area of peat in Orange County alone is 40,000 acres. Salt-marsh deposits occur on the shores of Long Island and adjoining parts of Westchester County. The origin of these deposits is similar to that of those on the coast of New England. As the peat is made up of the small variety of plants that tolerate salt water, it is relatively homogeneous but contains so much inorganic matter that it is of little value for fuel.

Newland[85] estimates that New York contains about 1,250 square miles of peat land, in which the deposits are 3 feet in average thickness. If this estimate is correct, the quantity of air-dried peat available in that State would be about 480,000,000 short tons. Approximately 75,000,000 tons of this peat is readily accessible.

The following notes contain a description of the deposits sampled for this bulletin. Further detailed data relating to the peat de-

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[85] Newland, D. H., New York State Mus. Bull. 102, p. 19, 1906.

posits of New York may be found in reports of the New York State Museum.[36]

CAYUGA COUNTY.

Locality 1.—A deposit west of the Erie Canal locks at Port Byron, Mentz Township, includes several hundred acres, and the peat is reported to have an average thickness of about 4 feet and to be underlain by 6 feet of marl. Onions, celery, and other truck crops are grown on this land, which appears to be more valuable for farming than for the production of peat. No samples were taken.

Montezuma Marsh, one of the largest areas of peat in New York, also lies partly in Cayuga County but is described in the discussions relating to Seneca and Wayne counties.

CLINTON COUNTY.

Locality 2.—A swamp along the shore of Lake Champlain at Kings and Catfish bays, about 2 miles south of Rouses Point, Champlain Township, which is heavily wooded with maple and elm trees, is covered with muck and impure peat from 6 to 18 inches thick, composed largely of the remains of leaves, twigs, roots, and small pieces of wood. Though usually flooded during the spring and early summer, this area is dry in the fall. Test borings gave the following results:

Thickness of peat and muck in test borings in swamp about 2 miles south of Rouses Point, Clinton County, N. Y.

	Feet.
Hole A, south end of swamp: Black sandy muck, underlain by sand	½
Hole B, 100 yards from west margin at point midway between north and south ends: Black impure peat containing woody matter	1½
Hole C, north end of swamp: Black muck	1½

Analysis 18 (p. 45), which shows the composition of a specimen taken from hole B, indicates that the material may be suitable for fertilizer but is unfitted for fuel.

Locality 3.—A swamp about 2 miles northeast of Plattsburg, extending from the north shore of Cumberland Bay, Lake Champlain, northward to Woodruff Pond and Bay St. Armand, contains a deposit about 500 acres in area and 2 feet in average thickness, which should yield approximately 200,000 short tons of air-dried peat and muck. The living vegetation consists of a large variety of plants, chiefly red maple, elm, swamp alder, tamarack, and scattered pine trees and shrubs, sphagnum moss, cat-tails, sedges, reeds, and other plants.

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[36] Ries, H., The uses of peat and its occurrence in New York: New York State Mus. Fifty-fifth Ann. Rept. (State Geologist, Twenty-first Ann. Rept.), pp. r55–r90, Albany, 1901. Parsons, A. L., Peat, its formation, uses, and occurrence in New York: New York State Mus., Fifty-seventh Ann. Rept. (State Geologist, Twenty-third Ann. Rept.), pp. 15–88, Albany, 1903.

The peat is dark brown and fibrous and contains much woody matter. The lower layers of muck contain a large proportion of sand. Test borings gave the following results:

Thickness of peat in test borings 2 miles northeast of Plattsburg, N. Y.

	Feet.
Hole A, north of wagon road, near southeast corner of swamp: Dark-brown woody peat and muck	2
Hole B, south-central part of swamp north of wagon road: Dark-brown woody, sandy peat and muck	2

Analysis 19 (p. 45), which was made on a sample taken from hole A, shows the deposit to be of fair quality for fertilizer but wholly unfit for fuel.

Locality 4.—Test holes in a marsh along both shores of Dead Creek, about 1½ miles north of Plattsburg, in Beekmantown and Plattsburg townships, revealed only a shallow deposit of brown to black silty muck, underlain by blue clay. This marsh occupies the lowlands along Dead Creek, and is subject to annual flooding. Its southern part is classed as locality 8. No samples were taken for analysis.

DUTCHESS COUNTY.

Locality 5.—A bog about 1 mile from the village of Fishkill, along the main highway, contains about 300 acres of peat 10 feet in average thickness and should yield approximately 600,000 short tons. A part of this bog is owned by Asa McElhone, of Fishkill, and the remainder by the Orchid Humus Fertilizer Co., of Peekskill. The peat is composite in origin, and the living vegetation is made up principally of maple, alder, and willow trees and cat-tails, reeds, grasses, and sedges. Sphagnum of the large-leafed variety, suitable for surgical dressings, was seen in some places. Many fern hummocks, the roots of which are gathered for orchid humus, occur throughout the bog. The peat, which appears to be of excellent quality for fuel or fertilizer, is dark brown to a depth of about 12 feet and green below this point. Test borings gave the following results:

Log of hole A, in south end of excavation at locality 5, 1 mile from Fishkill, N. Y.

	Feet.
Dark-brown fibrous peat	2
Dark-brown, well-decomposed firm peat	2
Dark-brown, well-decomposed plastic peat	8
Greenish plastic pond peat containing clay	2
	14

In hole B, at the north end of the same excavation, where peat is being produced, the peat is 13½ feet deep and is similar in texture and color to that in hole A.

Analysis 74 (p. 45) shows the character of a composite sample obtained by mixing peat taken at intervals of 2 feet to a depth of

12 feet in each of the two test holes described, and indicates that the peat is of good quality for fuel or fertilizer. Analysis 74a (p. 45) shows the character of a sample taken from a stock pile of peat excavated for fertilizer from the surface layer of the deposit and exposed to the weather for a year, and indicates that the peat is of excellent quality for fuel. The low ash content is due to the fact that the samples were taken from the upper layer of the deposit, where no inorganic material had been washed in by flood waters. This deposit contains a large quantity of peat of excellent quality for fuel or fertilizer. The Orchid Humus Fertilizer Co., of Peekskill, and Asa McElhone, of Fishkill, are producing peat from this deposit for fertilizer or stock feed.

FIGURE 4.—Map of Wickham Marsh, Essex County, N. Y., showing approximate position of test borings for peat.

Locality 6.—A deposit about 1 mile west of Hopewell Junction, worked by Norwin G. Cole, of Hopewell Junction, has produced peat for fuel and fertilizer for several years. The deposit is small but is reported to contain good peat to a depth of 10 feet.

Locality 7.—Stissing Pond, near Pine Plains, is surrounded by a peat deposit that is reported to be about 10 feet thick and to be underlain by marl.[37] Peat is now forming in the pond. The living vegetation, according to Parsons, consists of cat-tails, rushes, moss, and grasses.

ESSEX AND FRANKLIN COUNTIES.

Locality 8.—Test holes made in a marsh in Essex County, along the tracks of the Delaware & Hudson Co., south of the lower mouth of Ausable River, failed to show peat.

Locality 9.—Wickham Marsh, about 1 mile northwest of Port Kent, near the mouth of Marsh Brook, contains a deposit about 160 acres in area and 7 feet in average thickness, which should yield approximately 224,000 short tons of air-dried peat. (See fig. 4.) The living vegetation consists chiefly of tamarack, spruce, and alder trees, heath shrubs, ferns, moss, cotton grass, reeds, cat-tails, pitcher plants, sedges, and sphagnum. The peat, which is composed chiefly of the remains of mosses, sedges, and grasses, is brown and fibrous

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[37] Parsons, A. L., Peat, its formation, occurrence, and uses in New York: New York State Mus. Fifty-seventh Ann. Rept., pt. 1, p. 72, 1903.

in the upper layers but well decomposed at the bottom. Test borings gave the following results:

Logs of test borings in Wickham Marsh, 1 mile northwest of Port Kent, N. Y.

	Feet.
Hole A, about 100 yards south of north end of marsh near extremity of a north-south line through center:	
Brown fibrous peat, containing roots of living plants	1½
Brown fibrous peat, composed chiefly of moss, sedges, and grasses	2½
Brown soft plastic peat of uniform texture	9½
Hole B, 100 yards south of hole A:	
Brown fibrous peat	4
Dark-brown well-decomposed plastic peat	5
Hole C, 100 yards south of hole B:	
Light-brown fibrous peat	3
Dark-brown well-decomposed plastic peat	7
Hole D, 100 yards south of hole C: Light-brown fibrous peat	3
Hole E, 100 yards south of hole D, near south margin of deposit: Brown fibrous peat	2

Analysis 20 (p. 45) shows the character of a composite sample obtained by mixing peat taken at intervals of 2 feet in depth from each of the five test holes. It shows the peat to be low in ash and high in fixed carbon and nitrogen and therefore to be of good quality for fuel or fertilizer. Analysis 20a (p. 45) shows the composition of a specimen obtained by mixing peat taken from the upper 6 feet in each of the five test holes. The analysis shows only 6.87 per cent of ash. Better fuel could be made from this layer than from the lower layers, unless the peat is too fibrous. This deposit is well situated with respect to transportation facilities and contains some of the best peat in New York.

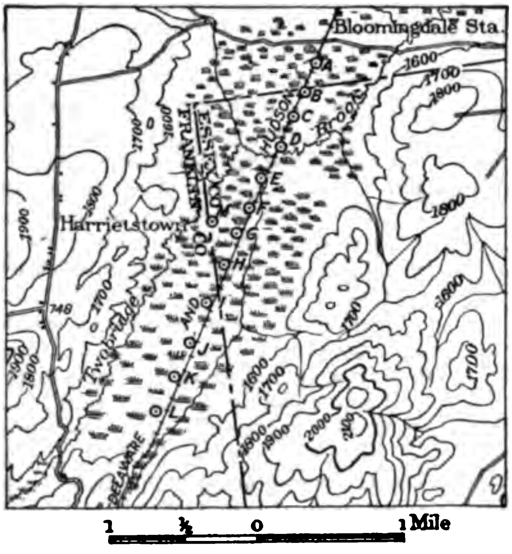

FIGURE 5.—Map of peat deposit southwest of Bloomingdale station, Essex and Franklin counties, N. Y., showing approximate position of test borings for peat.

Locality 10.—A sphagnum-heath bog extending along Twobridge Brook for about 3 miles southwestward from Bloomingdale station covers 1,500 acres, but not all of it is underlain by peat. (See fig. 5.) The tracks of the Delaware & Hudson Co. pass through the center of

the bog. The deposit of peat is about 700 acres in area and 5 feet in thickness and should yield approximately 700,000 short tons of air-dried peat. The living vegetation consists largely of heath shrubs, mosses, the blueberry, and cotton grass, though there are also a few scattered tamarack, spruce, and cedar trees. The deposit is of the built-up type and was formed on a flat, sandy, poorly drained surface. A series of test borings gave the following results:

Logs of test holes in bog 3 miles southwest of Bloomingdale station, Essex and Franklin counties, N. Y.

	Feet.
Hole A, about a quarter of a mile southwest of Bloomingdale station on east side of railroad track: Light-brown mossy fibrous peat	1
Hole B, about a quarter of a mile southwest of hole A: Same character of material as that in hole A.	
Hole C, about a quarter of a mile southwest of hole B: Same character of material as that in hole A.	
Hole D, about a quarter of a mile southwest of hole C: Same character of material as that in hole A.	
Hole E, about a quarter of a mile southwest of hole D, near bridge across Twobridge Creek: Light-brown mossy fibrous peat	2½
Hole F, about a quarter of a mile southwest of hole E:	
Light-brown mossy fibrous peat	2
Dark-brown decomposed plastic peat	4
Hole G, about a quarter of a mile southwest of hole F:	
Light brown mossy fibrous peat	2
Dark-brown well-decomposed plastic peat	6
Hole H, about a quarter of a mile southwest of hole G:	
Light-brown mossy fibrous peat	2
Dark-brown well-decomposed plastic peat	2
Hole I, about a quarter of a mile southwest of hole H:	
Light-brown mossy fibrous peat	2
Dark-brown well-decomposed plastic peat	3
Hole J, about a quarter of a mile southwest of hole I:	
Light-brown mossy fibrous peat	2
Dark-brown well-decomposed plastic peat of uniform texture	13½
Hole K, about a quarter of a mile southwest of hole J:	
Light-brown mossy fibrous peat	2
Brown well decomposed plastic peat of uniform texture	10
Hole L, about a quarter of a mile southwest of hole K, near south edge of bog: Light-brown mossy fibrous peat	2
Hole M, about a quarter of a mile west of hole F: Dark-brown fibrous mossy peat	2½

In hole K a layer of logs, roots, and woody matter was encountered at a depth of 12 feet that could not be penetrated with the sampling tool.

Analysis 21 (p. 45) shows the character of a composite sample obtained by mixing peat taken at intervals of 2 feet in depth from

, F, G, and M. It shows that the peat in the northern half bog contains only 6.54 per cent of ash and is therefore well d for fuel. The heating value is 9,125 British thermal units. is 22 (p. 45) shows the character of a composite sample ob- by mixing peat taken at intervals of 2 feet in depth from H, I, J, and K. It shows that the peat in the southern half bog is also of excellent quality for fuel. The peat contains a ercentage of nitrogen and hence might be used in the manu- e of commercial fertilizers.

lity 11.—Two heath bogs on opposite sides of the Delaware lson Co.'s track, at Middle Kilns. The largest bog contains 200 acres and lies south of the railroad station. The average ess of the peat in this bog orted to be about 6 feet. It cleared and could be readily d. If the area and depth rrectly estimated it should approximately 240,000 short f air-dried peat.

lity 12. — Sphagnum-heath n the Chateaugay branch of laware & Hudson Co.'s rail- a quarter of a mile south- f Onchiota. This bog covers 200 acres, and the deposit of s reported to be 5 feet in e thickness. It should there- ield approximately 200,000 ons of air-dried peat.

FIGURE 6.—Map of peat bog south of Lake Clear, Franklin County, N. Y., showing approximate position of test borings for peat (A, B, C, D).

lity 13. — A sphagnum- bog south of Lake Clear, 2 miles west of the rail- station at Lake Clear Junction, is about 200 acres in 2½ feet in average thickness, and contains about 100,000 ons of air-dried peat. (See fig. 6.) The Adirondack division New York Central Railroad skirts the north end of this bog. egetation consists chiefly of sphagnum and other mosses, heath , and spruce and tamarack trees. The peat is dark brown and fibrous and is composed chiefly of the remains of grasses and , except near the top, where moss peat predominates.

omposite sample, whose character is shown in analysis 23 (p. as obtained by mixing peat taken at intervals of 1 foot in depth ach of four test holes put down on a north-south line through nter of the bog. The peat appears to be low in ash and high d carbon and nitrogen, which indicates that it is of good qual-

ity for fuel or fertilizer. The deposit, however, is too shallow for the production of machine-peat fuel, though hand-cut peat might be obtained after the bog had been adequately drained.

Locality 14.—A series of test holes was made from northeast to southwest across certain areas south and east of the railroad station at Saranac Junction, on the Adirondack division of the New York Central Railroad, but no peat was found. The peat appears to have been destroyed by fire. The living vegetation is the same as that which grows on many peat bogs in the surrounding region and is therefore misleading.

Locality 15.—A bog containing peat extends from the southeast shore of Raquette Pond to the north shore of Tupper Lake and eastward along Raquette River. (See fig. 7.) The part of the bog adjacent to Raquette Pond and Tupper Lake is about 600 acres in area, and the peat is 5 feet in average thickness, so that the area would yield approximately 600,000 short tons of air-dried peat. This area was formerly a heavily wooded swamp, but the timber has been removed. The peat is dark brown and well decomposed; it contains some soft woody matter near the top and the remains of sedges, grasses, and cat-tails at the bottom. The surface is covered by a thin layer of mud, which has probably been deposited by recent floods. A series of test borings gave the following results:

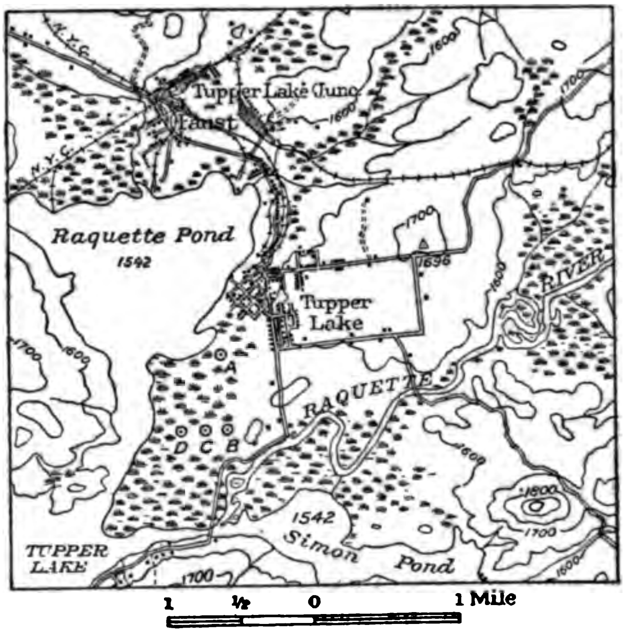

FIGURE 7.—Map of peat deposit northwest of Tupper Lake, Franklin County, N. Y., showing approximate position of test borings for peat.

Thickness of peat in test borings in deposit northwest of Tupper Lake, N. Y.

	Feet.
Hole A, near north end of deposit:	
Black muck	¼
Brown fibrous peat	¾
Dark-brown plastic peat	4
Hole B, near east-central part: Dark-brown plastic peat	4
Hole C, about 100 yards west of hole B: Same kind of peat as that in hole B	5½
Hole D, about 100 yards west of hole C: Same kind of peat as that in hole C.	

Analysis 24 (p. 45), of a sample taken from hole A, shows the peat in the northern part of the bog to be of good quality for fuel or fertilizer. Analysis 25 (p. 45) shows the character of a composite sample obtained by mixing peat taken at intervals of 1 foot in depth from holes B, C, and D, and indicates that the peat in the central part of the bog is also of good quality.

GENESEE AND ORLEANS COUNTIES.

Locality 16.—The Oak Orchard Swamp, which extends from Clarendon, Orleans County, westward for a distance of nearly 20 miles, is one of the largest in New York. (See fig. 8.) Much of the peat land in locality 16, which includes the eastern part of the swamp, 9 miles north of Batavia, in Genesee and Orleans counties, is owned by the Western New York Farm Land Co., of Batavia, N. Y. The average width of the swamp is about 2 miles. Approximately 10

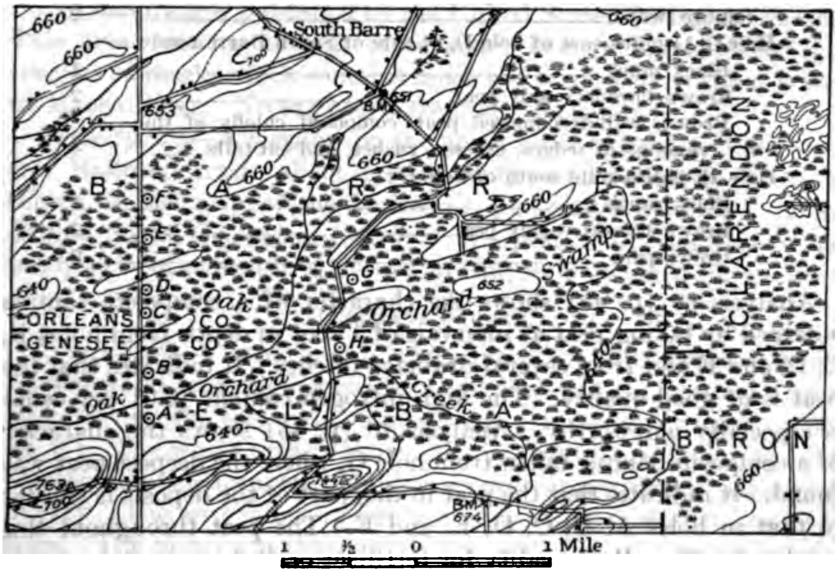

FIGURE 8.—Map of the eastern part of Oak Orchard Swamp, Genesee and Orleans counties, N. Y., showing approximate position of test borings for peat.

square miles of the total area is covered with peat. The peat is shallow throughout most of the swamp, especially in the western part, where the average thickness is only 3 feet. In the eastern part the peat ranges in thickness from 1 to 10 feet. The swamp probably would yield about 1,500,000 short tons of air-dried peat from beds 6 feet thick and an equal quantity from beds 3 feet thick. The early flora consisted of a dense growth of small plants as well as maple and other deciduous trees and some white cedar. However, the area has been largely cleared of trees and undergrowth, and thousands of acres are used for the growth of celery, lettuce, onions, and buckwheat.

A series of test borings in this locality gave the following results:

Logs of test borings in Oak Orchard Swamp, 9 miles north of Batavia, N. Y.

	Feet.
Hole A, near south edge of deposit at roadside: Black muck	1
Hole B, ½ mile north of hole A: Black woody, impure peat	2
Hole C, ½ mile north of hole B: Black woody, impure peat	3
Hole D, ½ mile north of hole C: Black woody, impure peat	3
Hole E, ½ mile north of hole D: Black woody, impure peat	3
Hole F, ½ mile north of hole E, edge of swamp: Black woody, impure peat	2
Hole G, 1½ miles east of hole D, at side of South Barre road:	
Black muck	1
Brown fibrous woody peat	2
Brown, well-decomposed peat, composed chiefly of the remains of sedges, grasses, rushes, and cat-tails	4
Hole H, half a mile south of hole G:	
Black muck	1
Brown fibrous woody peat	2
Brown peat	2

Analysis 69 (p. 45) shows the character of a composite sample obtained by taking peat at intervals of 1 foot in depth from holes B, C, D, and E and from several drainage ditches. It indicates that the peat is of good quality. The high nitrogen content (3.01 per cent) is especially noteworthy. Analysis 70 (p. 45) shows the character of a composite sample taken from hole G, where the deepest peat was found. It indicates that the peat in this part of the deposit is similar to that in holes A, B, C, D, E, and F. The peat throughout this locality is of excellent quality for fertilizer or fuel.

Locality 17.—Locality 17 includes the western part of the Oak Orchard Swamp, north of the villages of Alabama, Wheatville, and Oakfield, Alabama Township. The location and outline of this part of the swamp are shown on the map of the Medina quadrangle, published by the United States Geological Survey. As this locality has been described by Parsons, no borings were made. The average

thickness of the peat, which is underlain by marl, is reported to be about 3 feet. Parsons[38] says:

> North of Alabama the deposit can hardly be dignified with the name of peat, for it is drier than in the other portions and has a sandy subsoil and the peat contains a large percentage of foreign matter. The forest growth is principally made up of white cedar, though many deciduous trees are found. Sphagnum is not common but has been replaced by a moss of the genus *Hypnum.*

It therefore seems improbable that the western part of the Oak Orchard Swamp contains peat valuable for fuel.

HERKIMER COUNTY.

Locality 18.—A spruce bog north of Brandreth extends along both sides of Beaver River and several small tributaries near the west end of Nehasane Lake. The location and area of the deposit are shown on the map of the Big Moose quadrangle, published by the United States Geological Survey. The living vegetation consists chiefly of black spruce trees, sphagnum, and heath shrubs. The thickness of the peat was not determined and no samples were taken for analysis.

Locality 19.—A meadow along the north branch of Moose River, about 2 miles north of Old Forge, is shown on the map of the Old Forge quadrangle published by the United States Geological Survey. This area contains no peat of economic value. The surface layer consists of muck, which contains much silt washed in by the overflow of Moose River. No samples were taken for analysis.

Locality 20.—A meadow on the north side of the New York Central Railroad track, about 1 mile southwest of Fulton Chain, is shown on the map of the McKeever quadrangle published by the United States Geological Survey. The peat in this meadow is too sandy to be of economic value and no samples were taken for analysis.

ONONDAGA COUNTY.

Locality 24.—Cicero Swamp, which lies about 3 miles east of North Syracuse and an equal distance south of Oneida Lake, is several miles long, though the east end contains some patches of dry land. (See fig. 9.) The whole area is shown on the maps of the Syracuse and Chittenango quadrangles published by the United States Geological Survey. The area shown in figure 9 is about 8 square miles, or 5,120 acres. The maximum thickness of the peat shown in test holes was 11 feet, but it is reported that the peat is 15 feet deep in some places. An area of about 3,500 acres is covered with peat 6 feet deep and 1,500 acres with peat 4 feet deep. The quantity of peat available in locality 24 is estimated to be equivalent to 5,400,000 short tons of air-dried peat. The area is composite in origin. Most of the peat is of the built-up type, though pond-peat is found in some places, indi-

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[38] Parsons, A. L., op. cit., pp. 83–85.

cating that the bog was formed on a large flat, poorly drained surface that contained small basins. Marl underlies the peat in some places. The living vegetation consists chiefly of spruce, tamarack, and cedar trees, heath shrubs, and sphagnum. Near the center of the swamp there is a large open sphagnum heath similar to those in Maine, Minnesota, and eastern Canada. Around the margin of the swamp stretches a zone one-fourth of a mile wide of deciduous trees, chiefly red maples. Plate XI, *A*, shows the general appearance of the swamp. The peat, which is composed chiefly of the remains of sphagnum moss, heath shrubs, and grasses, is brown, fibrous to well-decomposed, soft, and plastic. The upper layers contain some woody matter. A series of test boring gave the following results:

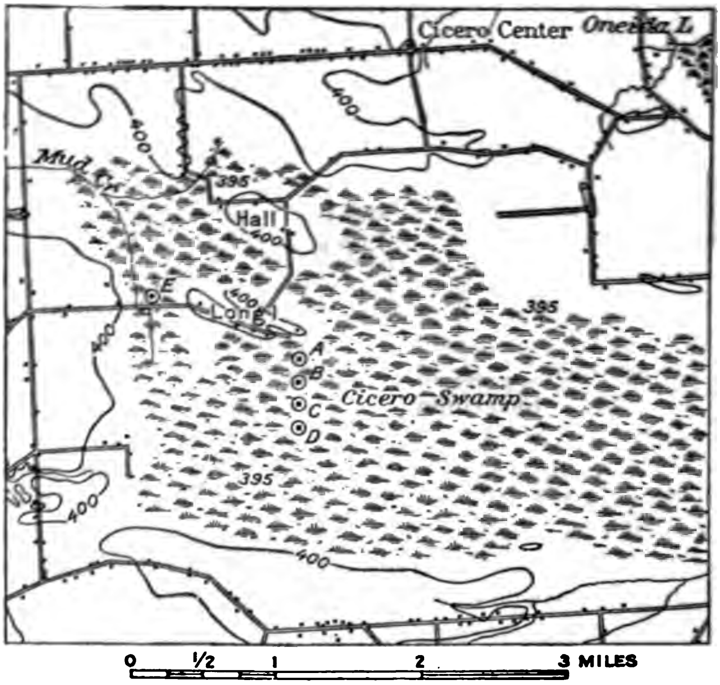

FIGURE 9. Map of part of Cicero Swamp, Onondaga County, N. Y., showing approximate position of test borings for peat.

Logs of test borings in Cicero Swamp, near North Syracuse, N. Y.

	Feet.
Hole A, south of east end of Long Island: Black woody impure peat	2
Hole B, one-eighth of a mile south of hole A:	
Black woody peat and muck	2
Brown plastic peat	2
Hole C, one-eighth of a mile south of hole B:	
Brown fibrous peat containing woody matter	2
Dark-brown well-decomposed peat	3½

A. NATIVE SECTION OF CICERO SWAMP, ONONDAGA COUNTY, N. Y.

B. RECLAIMED PEAT SWAMP IN THE WALLKILL RIVER VALLEY NEAR BIG ISLAND, ORANGE COUNTY, N. Y.

Used for the cultivation of onions.

THE WINNING OF A PEAT SWAMP.

	Feet.
Hole D, one-eighth of a mile south of hole C:	
Brown fibrous peat, containing the remains of sphagnum	2
Dark-brown well-decomposed plastic peat of uniform texture	7½
Hole E, midway between the west end of Long Island and the west edge of the swamp:	
Brown fibrous, woody peat	3
Brown well-decomposed plastic peat of uniform texture	8

nalysis 64 (p. 45) shows the composition of a composite sample ained from hole D and indicates that the peat near the center of swamp is of excellent quality for fuel or fertilizer. The ash con- t is only 7.34 per cent and the nitrogen 2.02. The calorific value ,256 British thermal units. Analysis 65 (p. 45), which shows the racter of a composite sample taken from hole E, indicates that the t near the western edge of the deposit is similar to that in the ter.

icero Swamp is well situated for the production of peat fuel or tilizer, and the deposit contains a large quantity of good peat. ch of the deposit is underlain by marl, which could be economically d in neutralizing the peat. A large area of peat at the west end the swamp is used for the growth of truck crops.

ocality 25.—A deposit about 1½ miles northwest of North Syra- e, Clay Township, which is about 1,500 acres in area and 10 feet average thickness, should yield about 3,000,000 short tons of air- ed peat. The peat, which is made up chiefly of the remains of ges, grasses, leaves, and shrubs, is dark brown, well decomposed, stic, and of uniform texture. The early flora consisted chiefly of iduous forest trees and partly of spruce and tamarack, but the es have been cut, and a large part of the area has been drained cleared and is cultivated. Onions, celery, and lettuce are the ncipal crops grown. A series of test borings gave the following ults.

s of test borings in peat deposit 1½ miles northwest of North Syracuse, N. Y.

	Page.
Hole A, about 50 yards north of south edge and three-fourths of a mile from east end:	
Brown fibrous peat	1
Brown well-decomposed firm peat	4
Hole B, about 150 yards north of hole A:	
Brown fibrous peat, dry and earthy	1
Brown well-decomposed dry peat	2
Brown well-decomposed plastic peat of uniform texture	8½
Hole C, about 100 yards north of hole B in center:	
Brown dry fibrous earthy peat	1
Brown well-disintegrated dry peat	2
Brown well-decomposed plastic peat	12

nalysis 66 (p. 45) shows the composition of a composite sample ained from hole B and indicates that the peat is well adapted for l or fertilizer.

ORANGE COUNTY.

Locality 26.—A small deposit about 2 miles from Monroe on the Woodhuld farm occupies a filled basin that is underlain by marl. The living vegetation consists of cat-tails, grasses, and sedges. The deposit is less than 1 acre in area, is 4 feet in average thickness, and contains only about 500 short tons of air-dried peat. A thin layer of black muck covers the surface of the deposit. The upper layers of peat are fibrous, and the lower layers, which are underlain by marl, are well decomposed. Analysis 71 (p. 45) shows the composition of a specimen from this deposit and indicates that the peat is of good quality for fertilizer. This peat area, though small, is described because the owners, Woodhuld & Lamereaux, have produced peat fertilizer from it for many years. There was no production in 1918 because of the small quantity of peat in the deposit, and it is believed that no further production will be attempted.

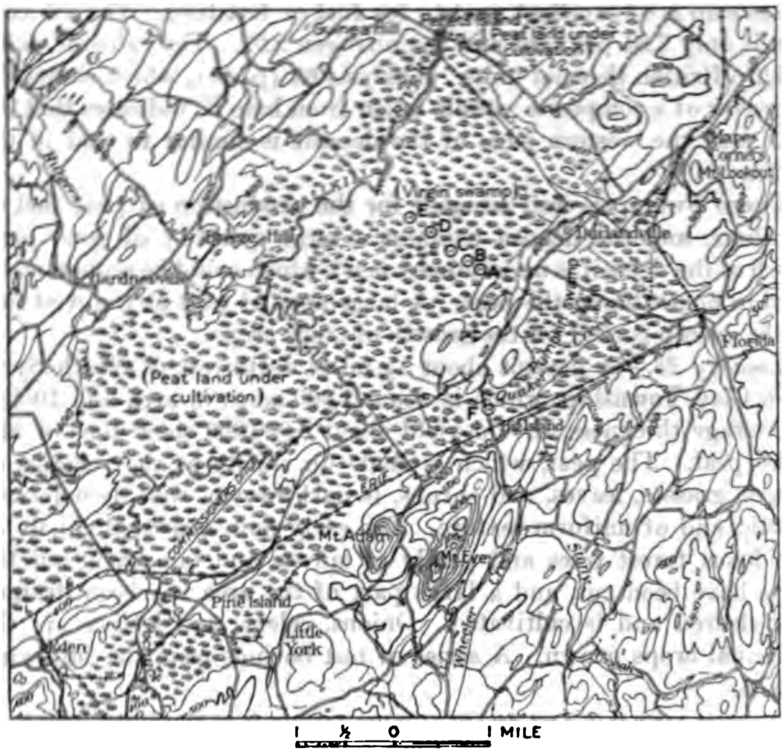

FIGURE 10. Map of the "drowned lands" of Wallkill River valley, Orange County, N. Y., showing approximate position of test borings for peat.

Locality 27.—The "drowned lands" of the Wallkill River valley extend through Warwick, Wawayanda, and Goshen townships. (See fig. 10.) Florida, Big Island, Pine Island, and Durlandville

are situated along the southern margin of this swamp, which is about 17,000 acres in area and is underlain by peat that ranges in thickness from 1 to 25 feet. An area of about 10,000 acres is underlain by peat 10 feet deep. This deposit should yield approximately 20,000,000 short tons of air-dried peat. The greater part of the area has been cleared and drained and is cultivated. The earlier vegetation, a living remnant of which may still be seen about 2 miles northwest of Big Island, consisted of spruce, tamarack, cedar, and red maple trees, shrubs, cat-tails, rushes, sedges, grasses, and mosses. The peat is dark brown and fine grained except near the bottom, where green pond peat occurs. Little fibrous peat was found, and no roots or buried logs are present except near the surface. A series of test borings gave the following results:

Logs of test borings in the "drowned lands" of Wallkill River valley, N. Y.

	Feet.
Hole A, 1½ miles north of Big Island, near east edge of undrained section:	
Brown disintegrated peat, containing some woody matter	2
Dark-brown well-decomposed plastic peat of uniform texture, underlain by clay	8
Hole B, about 100 yards northwest of hole A:	
Brown woody peat	2
Dark-brown well-decomposed plastic peat, uniform in texture	8
Greenish fine-grained pond peat	4+
Hole C, about 100 yards northwest of hole B: Same kind of peat as that in hole B	10
Hole D, about 100 yards northwest of hole C: Same kind of peat as that in hole B.	
Hole E, about 100 yards northwest of hole D: Same kind of peat as that in hole B.	
Hole F, about a quarter of a mile northwest of Big Island, in area known as the "Pumpkin Swamp":	
Brown dry well-disintegrated earthy peat	3
Dark-brown thoroughly decomposed plastic peat, of uniform texture	9
Greenish fine-grained clayey pond peat	2

Parsons[39] gives the following results of test borings for peat at other places in this locality:

Depth of peat in test borings in "drowned lands" of Wallkill River valley, N. Y.

	Feet.
Boring on Black Walnut Island	18 +
Boring half a mile west of Durlandville	16
Boring 1½ miles west of Durlandville	17
Boring half a mile west of Big Island	12½+
Boring 1 mile west of Big Island	12½+
Boring at Florida	18 +
Boring on Pine Island	18 +

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[39] Parsons, A. L., op. cit., p. 70.

Analysis 72 (p. 45) shows the character of a composite sample obtained by mixing material taken at intervals of 1 foot in depth from hole B. It shows that the peat is low in ash (13.68 per cent) and high in nitrogen (2.89 per cent) and therefore is suitable for fuel and fertilizer. Analysis 73 (p. 45) shows the character of a composite sample from hole F. It indicates that the peat in this part of the deposit contains a higher proportion of inorganic matter than that in the vicinity of hole B. The nitrogen content of both samples is relatively high. This deposit, which contains peat of excellent quality for both fuel and fertilizer, is the largest in New York. The area is extensively used for the cultivation of onions and other crops and is probably more valuable for this use than for the production of peat for fuel. (See Pl. XI, *B*.) The onions are grown on relatively pure peat. About 2,000 acres of the Wallkill Swamp are undrained.

ST. LAWRENCE COUNTY.

Locality 28.—A bog west of Horseshoe Lake, about half a mile south of Horseshoe station, Piercefield Township, is shown on the map of the Tupper Lake quadrangle, published by the United States Geological Survey. This bog is about 250 acres in area. The peat is shallow and therefore of doubtful value.

Locality 29.—A bog on the east shore of Hitchins Pond, Colton Township, is about 200 acres in area and 4 to 5 feet in average thickness. This deposit should yield approximately 180,000 short tons of air-dried peat. The surface is smooth and is overgrown by sphagnum moss and heath shrubs.

SENECA AND WAYNE COUNTIES.

Montezuma Marsh, north of Cayuga Lake, is divided at the north end into two arms, one extending along Seneca River and the other along Clyde River. Below the junction of these rivers the marsh is broad and extends to Cayuga Lake. Its area and location are shown on the maps of the Auburn, Clyde, Geneva, and Weedsport quadrangles published by the United States Geological Survey. Its maximum length from Cayuga Lake northward to Spring Lake is about 14 miles. The total area of the Montezuma Marsh is approximately 24 square miles; the two northern branches are each about 7 square miles in area, and the widest part, at the north end of Cayuga Lake, near the junction of Clyde and Seneca rivers, is about 10 square miles in area. Only a part of the marsh contains peat and muck, much of which is shallow. In the northern part of the eastern branch the average thickness of the deposit is only 3 feet. Farther south toward the center and also in the western branch along Clyde River the deposit is deeper. The part adjoining the north end of Cayuga Lake contains filled-basin peat and muck underlain by marl, a condition which indicates that the lake formerly extended farther north

its present shore line. The living vegetation on the margin he marsh consists of small willow, maple, and alder trees, h grow in a zone one- th to one-half mile . In the area sur- ided by this zone the inant plants are cat- , sedges, and marsh ses, which are gathand sold for packing rial and chair seats. peat is fibrous to plasand rather impure. greater part of the rial in this deposit is k. A strong odor of ogen sulphide was eable when the holes put down. Because ie large area of Mon- ma Marsh the char- of the peat in its northern branches, i both of which sam- were obtained, is de- ed separately.

cality 30.—Locality see fig. 11) includes northeast branch of narsh extending along ca River. It is esti- d that the deposits his locality, much of ch is underlain by , should yield 2,500,000 short tons of air-dried peat. A series st borings gave the following results:

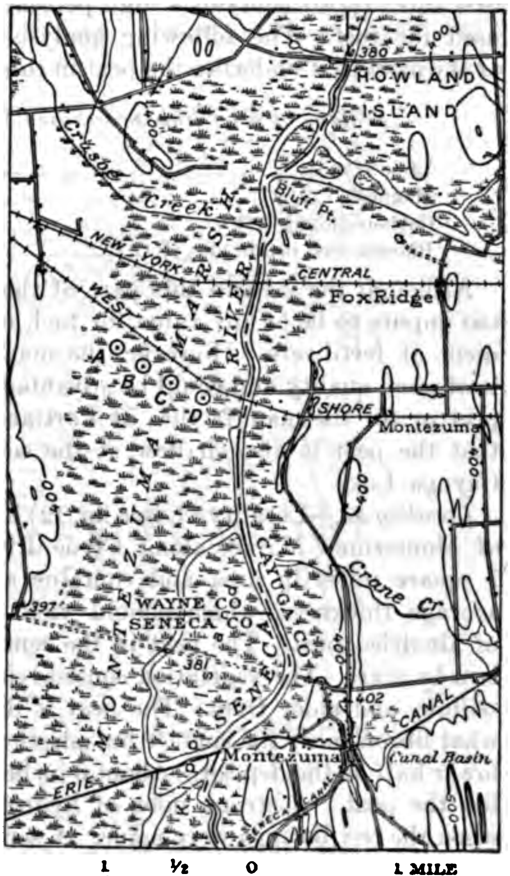

FIGURE 11.—Map of the northeastern part of Montezuma Marsh, Seneca and Wayne counties, N. Y., showing approximate position of test borings for peat.

of test borings in northeastern part of Montezuma Marsh, on Seneca River, N. Y.

	Feet.
Hole A, about 1 mile west of Seneca River, on the south side of the tracks of the West Shore Railroad: Black muck	1
Hole B, about one-fourth of a mile east of hole A:	
Black muck	1
Dark-brown plastic peat	3
Hole C, about one-fourth of a mile east of hole B:	
Black muck	1
Black plastic peat	2
Hole D, about one-fourth of a mile east of hole C: Black sandy muck	1

Analysis 67 (p. 45) shows the character of a composite sample obtained by mixing material from holes B and C. It indicates that this deposit contains a high percentage of ash and could not be used for fuel. The following analysis represents the composition of the marl that underlies the peat in this locality:

Analysis of marl from Seneca and Wayne counties, N. Y.

Lime (CaO)	45.75
Magnesia (MgO)	1.21
Carbon dioxide (CO_2)	35.32
Phosphorus pentoxide (P_2O_5)	None.

Although the peat in this part of the deposit is too shallow and too impure to be of any value for fuel, it might be used as an ingredient of fertilizers. However, the marl that underlies the deposit is of good quality and could be advantageously used for treating the peat or for the manufacture of Portland cement. Parsons[40] states that the peat is also shallow at the south end of the marsh near Cayuga Lake.

Locality 31.—Locality 31 (see fig. 12) includes the northwest branch of Montezuma Marsh, along Clyde River. This branch is about 7 square miles in area and contains a deposit of peat 4 feet in average thickness, which should yield about 3,500,000 short tons of air-dried peat. The peat in the center of this locality is underlain by marl. The vegetation consists chiefly of cat-tails and maple, willow, and alder trees. The peat is dark brown, firm, and somewhat fibrous near the surface but plastic and well decomposed in the lower half of the deposit. About 6 inches of black sandy muck overlies the peat. A strong odor of hydrogen sulphide was noticeable when the test borings were made. A series of holes gave the following results:

Logs of test borings in northwestern part of Montezuma Marsh, Seneca and Wayne counties, N. Y.

	Feet.
Hole A, about a quarter of a mile west of the east edge of the marsh along the New York Central Railroad: No peat found.	
Hole B, about a quarter of a mile west of hole A:	
Black sandy peat	½
Black fibrous peat	1½
Hole C, about a quarter of a mile west of hole B:	
Black sandy muck	½
Brown fibrous peat	1½
Brown plastic peat	5
Hole D, about a quarter of a mile west of hole C:	
Black sandy muck	½
Brown fibrous to disintegrated peat	3½

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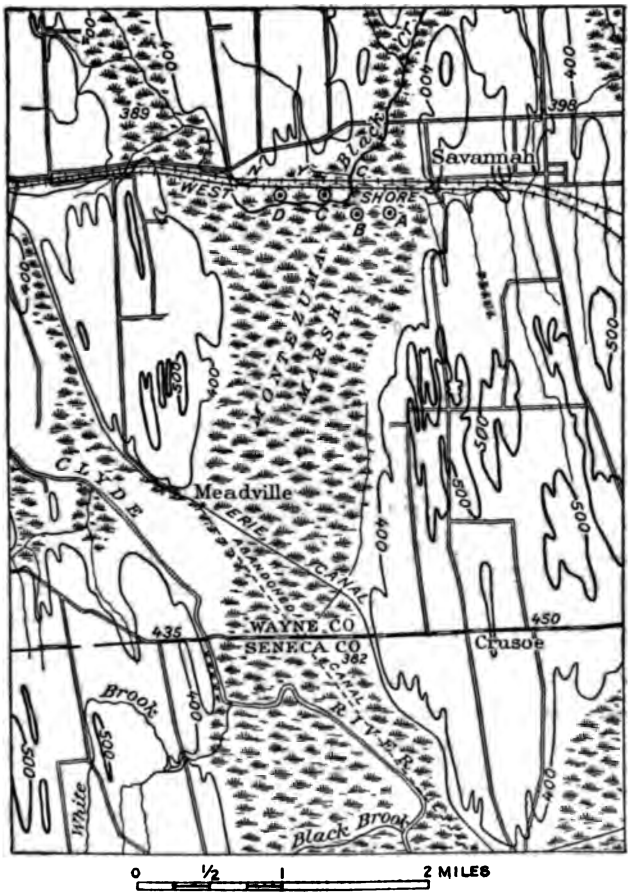
[40] Parsons, A. L., op. cit., p. 82.

nalysis 68 (p. 45), which represents the character of a composite ple from holes C and D, shows that the material may be suitable agricultural use, but is too high in ash for fuel. Locality 31 tains better peat and muck for agricultural use than locality 30 l is well situated for development, though drainage might be icult during the high-water stages of Cayuga Lake and Clyde er. Several large drainage ditches already have been constructed. e marl underlying much of the peat is valuable for agricultural or for the manufacture of Portland cement.



RE 12.—Map of the northwestern part of Montezuma Marsh, Seneca and Wayne counties, N. Y., showing approximate position of test borings for peat.

NEW JERSEY.

GENERAL FEATURES.

s shown on the accompanying map (Pl. XII), Bergen, Essex, dson, Mercer, Middlesex, Morris, Passaic, Somerset, Sussex, ion, and Warren counties, in the northern half of New Jersey,

contain most of the peat in that State. The best and most extensive deposits occur in the Sprout Brook Meadow, Bergen County; in the Black, Bog and Vly, Troy, Vernon, and Sussex meadows, Morris County; and in the Pequest Meadows, Warren County. Some peat is also found along the coast. The deposits of northern New Jersey are chiefly of the meadow type, although there are a few spruce and cedar swamps in the State. The greater part of the peat originated in glacial lakes and ponds and should, therefore, be classed with the peat in the region of the Great Lakes and the New England States. Although most of the deposits in salt marshes along the coast of New Jersey, like many of those along the coast of New England, are related in origin and composition to those in the States of the southern Atlantic coastal region, these salt marshes are in this report classed with the major areas of peat accumulation of the northern region. It is estimated that about 15,000,000 short tons of air-dried peat could be obtained from the deposits in New Jersey.

FIGURE 13.—Map of peat deposit in Byram Township, Sussex County, N. J., showing approximate position of test borings for peat.

A detailed description of many of the valuable peat deposits in New Jersey is given in a report by Parmelee and McCourt.[a] The following deposits from which peat has been produced commercially were examined in order to obtain data for this report.

SUSSEX COUNTY.

Locality 1.—A deposit in Byram Township, about 2½ miles north of Netcong, which is about 150 acres in area and 10 feet in average thickness, should yield approximately 300,000 short tons of air-dried peat. (See fig. 13.) Formerly the area was covered by a heavy growth of broad-leaved trees, among which the maple predominated. A large part of the surface has been cleared, and in other places there is a growth of cat-tails, sedges, grasses, and small shrubs. The de-

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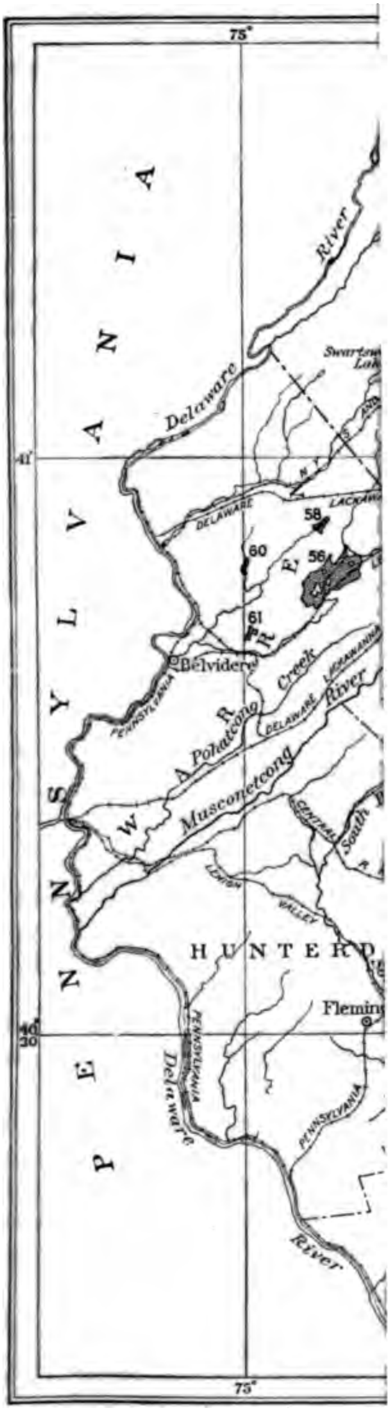
[a] Parmelee, C. W., and McCourt, W. E., A report on the peat deposits of northern New Jersey: New Jersey Geol. Survey Ann. Rept. for 1905, pp. 223–313, 1906.

U. S. GEOLOGICAL SURVEY



MAP SHOW

sit originated in a lake or pond, but the upper layers consist of ilt-up peat formed by the accumulation of the remains of plants at gained a foothold upon the peat after the basin had been filled. ie origin is plainly shown in the structure of the deposit. The wer portion consists of greenish pond peat that is composed en- ely of the remains of aquatic plants, such as pondweed and water ies. Above this part, extending from the surface to a depth of out 10 feet, the peat is brown and is composed of the remains of asses, sedges, mosses, cat-tails, shrubs, and other plants that grow ly near the ground-water level. Several test holes put down in the rthern half of the deposit gave the following results:

Logs of test borings in Byram Township, Sussex County, N. J.

	Feet.
Hole A, near north end of deposit in cleared area:	
Brown fibrous peat, containing roots and pieces of wood	2
Brown fibrous peat	2
Brown well-decomposed peat	3
Yellowish-brown plastic clayey peat	1
Hole B, in center of cleared area, southeast of hole A:	
Brown fibrous peat, containing roots and pieces of wood	2
Brown fibrous peat	2
Brown plastic peat, of uniform texture	4
Greenish soft pond peat	3½
Hole C, about 100 yards southeast of hole B:	
Black earthy peat	1
Brown fibrous peat, containing pieces of wood and roots	3
Brown fibrous peat, free from wood	2
Brown well-decomposed plastic peat of uniform texture	4
Greenish clayey soft pond peat	5+

A composite sample (analysis 1, p. 44) from the upper 10 feet was tained by mixing peat taken at intervals of 2 feet in depth from ch of the test holes. The analyses show that the peat in the upper feet is of good quality for fertilizer or for fuel. Peat fertilizer is ing produced from this deposit by the Commercial Humus Co., of wark, N. J. The peat is excavated by hand, loaded into wooden im cars, and hauled by cable to the loading station, where it is icerated and discharged into a large rotary drier. From the drier disintegrated peat is loaded directly into railroad cars. The oduct is used as a nitrogenous ingredient of commercial fertilizers. r several years a small quantity of peat fertilizer has been annually oduced at this plant. Analysis 2 (p. 44) shows the quality of the w peat excavated for fertilizer.

WARREN COUNTY.

Locality 2.—The plant of the Alphano Humus Co., of New York, Y., is located on the deposit in the Pequest Meadows, which ex-

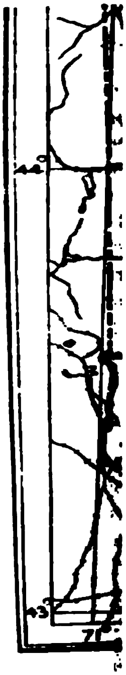
tend along Pequest River from Danville to Long Bridge. (See 14.) About 2,000 acres, which it is estimated would yield appr mately 1,600,000 short tons of air-dried peat, is said to be contro by this company. The deposit is used for the growth of celery, oni lettuce, and other truck crops, and for the production of peat

FIGURE 14.—Map of peat deposit along Pequest River, Warren County, N. J.

tilizer. This locality contains some of the best peat in the Uni States and is well situated with respect to transportation facili and market.

MAINE.

The most accessible peat deposits in Maine occur in Androscog Cumberland, Kennebec, Knox, Lincoln, Oxford, Penobscot, Wal Washington, and York counties. (See Pl. XIII.) All these co ties lie in the eastern and southern parts of the State and traversed by railroads. Aroostook, Piscataquis, and Somerset co


42°
43°
71

s, in the northern and western parts of Maine, also contain large posits of peat, but on account of the lack of transportation facili- s in this region little is known concerning the quality of this peat. ıstin and Davis[42] say that peat resources as great or greater than ose of southern Maine occur in the forested lake districts of the rthern part of the State. Most of the northern deposits, like ıny of those in northern Minnesota and Michigan, are situated heavily forested swamps, containing deep standing water, and tempts will hardly be made to use the peat for many years. Ac- rding to Burr,[43] nearly all the peat in Maine that will be used mmercially for several years lies between the coast and a line awn from Houlton to the Rangeley lakes.

The built-up deposit formed on relatively flat or gently sloping nd surfaces is the predominant type in Maine and, to the scientist, e climbing bog, a variety of this predominant type, is of most inter- t. The predominance of built-up peat in Maine is ascribed to the tensive flat, undrained areas and to the cool humid climate, con- tions favorable to the growth of sphagnum, heath shrubs, and asso- ated coniferous trees. The largest and deepest of these deposits cur in the northern part of the State. The climbing bogs of aine are described by Shaler[44] as follows:

> Although bogs are ordinarily formed beneath lake basins by the gradual owth of water-loving vegetation from their sides and bottoms, a process ıich goes on until the lake may be converted into a normal peat swamp, there another way in which peat may be accumulated and which in certain regions res rise to very extensive bogs which were not formed in a water basin; ese are commonly known as climbing bogs, and in one or another of their reral forms they are widely disseminated. In high latitudes peat deposits e due to the growth in a luxuriant form of the common sphagnum. Starting the borders of a lake basin, the dense mass of branches of this plant will, the air be very moist, grow not only over the surface of the water but upward m its level upon slopes which may have an inclination of 5° or 10°. As lower part of the vegetable mat decays it forms a peat of ordinary quality, ich may gradually attain a thickness of many feet. In the process of growth se highland morasses often extend into forests, where they gradually kill trees, so that the region once wooded may become an open moorland.
>
> n eastern Canada, Newfoundland, and the Maritime Provinces, climbing s of the type so common in Ireland and other portions of northwestern rope occur, but they lack the extent and depth of those in the Old World. thin the United States the only climbing bogs of a conspicuous character ur in eastern Maine, but even there they are relatively unimportant except m a scientific point of view. Similar accumulations of a smaller sort med on declivities may be noted in the more western parts of New Eng- d and in northeastern New York. Nowhere within the limits of the United

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[42] Bastin, E. S., and Davis, C. A., Peat deposits of Maine: U. S. Geol. Survey Bull. , p. 113, 1909.

[43] Burr, F. F., The peat deposits of Maine: Public Utilities Commission of Maine Second . Rept., p. 71, 1916.

[44] Shaler, N. S., Origin, distribution, and commercial value of peat deposits: U. S. Geol. vey Sixteenth Ann. Rept., pt. 4, pp. 308 and 311, 1895.

States, so far as is known to the writer, are these high-lying bogs of other than scientific interest.

Although some filled-basin peat is found in Maine, relatively few deposits contain only that kind. The deposit on the east shore of Pushaw Lake, about 8 miles north of Bangor, is one of the largest filled-basin deposits. In most places this type underlies built-up peat.

According to Burr[45] and Bastin and Davis,[46] a total area of 50 square miles of readily accessible peat 8 feet in average depth has been examined. These deposits are estimated to be capable of yielding 48,000,000 short tons of air-dried peat. However, in addition to this quantity, there are large bogs and swamps in the northern forested region as well as in relatively inaccessible southern areas that probably contain a quantity as large or larger. It is believed that the peat deposits of Maine would yield at least 100,000,000 short tons of air-dried peat. The following table[47] gives a brief description of the most readily accessible peat deposits in Maine. Analyses of the peat are given on pages 30–33.

Peat deposits in Maine.

Location.	Distance from railroad (miles).	Floral condition.	Area (acres).	Average depth (feet).	Quantity of air-dried peat available (short tons).	Remarks.
ANDROSCOGGIN COUNTY.						
East Livermore	3	Forested	300	10	600,000	
Greene	1	Open heath	160	6	250,000	
Lewiston:						
Farwell Bog	2	.....do	130	15	400,000	
No Name Bog	3	.....do	125	15	400,000	
Leeds:						
West of Center	2	.....do	100	4	80,000	
South of Center	2	.....do	200	15	600,000	
North of Center	1	.....do	2	20	8,000	
AROOSTOOK COUNTY.						
Bancroft	2	Cedar swamp	200	2(?)	Little.	
Crystal	2	Partly wooded	100	5	100,000	
Do	1	.....do	60	9	25,000	
Squa Pan	1	Densely wooded	200	2	Little.(?)	
Bancroft, east of	Near.	Open heath	100	10	200,000	
Do	Near.	Cedar swamp	100	2	....	Not promising.
Wytopitlock	Near.	Wet wooded bog	150	(?)	....	Do.
Houlton, southwest of.	Near.	Open heath	30	4	25,000	
Sherman	Near.	Partly wooded	50	7	70,000	
CUMBERLAND COUNTY.						
Brunswick, College Bog.	2	Shrubby heath	160	3–	Little.	Local use
Cape Elizabeth	....	Part wooded	100	10	225,000	
Falmouth	5	.....do	85	15	250,000	
Sebago, Northwest River.	8	Swamp	600	(?)	(?)	
HANCOCK COUNTY.						
Bucksport, Mud Pond.	5	Open heath	20	10	40,000	
Nicolin	1	.....do	12	10	25,000	
FRANKLIN COUNTY.						
Chesterville	5	Open heath	300	6	300,000	

[45] Burr, F. F., op. cit.

[46] Bastin, E. S., and Davis, C. A., op. cit.

[47] Burr, F. F., op. cit., pp. 73–75.

Peat deposits in Maine—Continued.

ation.	Distance from railroad (miles).	Floral condition.	Area (acres).	Average depth (feet).	Quantity of air-dried peat available (short tons).	Remarks.
C COUNTY.						
	2		Small.	Shallow.		Impure, clayey.
onskee Lake	1–	Cat-tail swamp	500	2		Poor quality.
Pond	6	Mostly wooded	300	4		Very wet, unavailable.
	Near.	Open heath	5	14	14,000	
	4	Open heath	100	6	120,000	
outhwest of.	Near.	Part wooded	10	15	30,000	
North	1	Open center	300	15	900,000	
reat Sidney	5	Open heath	640	20	2,500,000	Fibrous.
)	2	Partly open	30	7	40,000	
y Pond	3	Open heath	10	10	20,000	
el Pond	5	Open bog	60	15	180,000	Available?
ast	5	Open heath	5	10	10,000	
	5–	do	100	20	400,000	
COUNTY.						
	3	do	150	8	240,000	
COUNTY.						
east of	2	Open, grassy	100	8	160,000	Quality uncertain.
	Near.	Open	80	10	160,000	
utheast of.		Wet and grassy	200	(?)		Doubtful.
orth of	Near.	Open	Small.	2–	(?)	
g place	4–	do	3	8	4,800	
Kezar Pond	5	2 shallow bogs	600	(?)		Not promising.
T COUNTY.						
	2	Open heath	640	9	1,150,000	
	Near.	Largely wooded	1,000	8	1,600,000	
	Near.	Wooded	200	12(?)	480,000(?)	
	Near.	Partly wooded	300	8	480,000	
on bog	1	do	600	10	1,200,000	
	Near.	Largely open	400	10	800,000	
, west of	Near.	Open heath	200	6	240,000	
	Near.	do	30	5	30,000	
, Pushaw	3	Variable	5,760	5(?)	5,700,000	Probably more.
	3	Open	300	8	400,000	
UIS COUNTY.						
le	Near.	2 open heaths	300	6	360,000	
nville Junc-.	Near.	Partly wooded	Small.	(?)		Might yield some peat.
T COUNTY.						
north of	Near.	Heavily wooded	2,000	(?)	Uncertain.	
	Near.	Partly wooded	(?)	(?)	(?)	
north of	2	Largely wooded	400	6	480,000	
southeast of.	1	Open moss	500	10	1,500,000	
l, northwest Pond.	5	do	300	15	1,000,000	Best in the State.
ON COUNTY.						
r	10	Partly wooded	Large.	(?)	Uncertain.	
northeast of.	1	Open moss	5	3	3,000	
d, north of	2	Open heath	40	6	48,000	
	7	do	3,000	5(?)	3,000,000	
dic Lake	7	do	1	15	3,000	
ias, north of.	7	Open moss	50	10	100,000	
ern Inlet	Near.	do	60	10	120,000	
Falls, River.	2	Grassy marsh	6,000	Little.	Doubtful.	
rthwest of	Near.	Open moss	30	10	60,000	

Peat deposits in Maine—Continued.

Location.	Distance from railroad (miles).	Floral condition.	Area (acres).	Average depth (feet).	Quantity of air-dried peat available (short tons).	Remarks.
Jonesboro:						
Whitneyville	Near.	Open moss	20	8	30,000	
Pond Cove		do	40	5	40,000	
Roque's Bluff		Open heath	15	5	15,000	
Black Head		do	10	10	20,000	
Jonesport, east of	8	do	40	10	80,000	
Jonesport, north of	7	do	20	6	24,000	
Lubec: Quoddy Head		Open, wave-cut	20	5	20,000	
Pembroke:						
Ayers Junction	Near.	Open moss	160	15	250,000	
Do	Near.	Open moss, sedgy	50	5	50,000	
Falls Point		Open heath	35	10	70,000	
Perry			10	3	6,000	
Trescott, south of		Open moss	160	8	200,000	
Vanceboro, west of	Near.	Partly open	500	10	1,000,000	
Danforth, west of	Near.	Largely wooded	300	6(?)	300,000(?)	

NEW HAMPSHIRE.

GENERAL FEATURES.

Cheshire, Hillsborough, Rockingham, and Sullivan counties contain the largest and most valuable peat deposits in New Hampshire. Some peat is also found in Belknap and Coos counties. Although there are a few salt-marsh deposits on the coast, notably near North Beach, Greenland, and Hampton Beach, most of the peat originated in fresh-water basins. The deposits of New Hampshire are estimated to be capable of yielding 1,000,000 short tons of air-dried peat, a quantity much less in proportion to the size of the State than is found in the other New England States. This condition is ascribed to the roughness of the land surface and to the lack of extensive poorly drained depressions.

CHESHIRE COUNTY.

Locality 1.—A deposit 1 to 1½ miles south of East Jaffrey contains about 50 acres of peat, 6 feet in average thickness, and should yield approximately 60,000 short tons of air-dried peat. (See fig. 15.) The vegetation consists chiefly of spruce, tamarack, and maple trees, heath shrubs, blueberry, sedges, and grasses. A series of test borings gave the following results:

Thickness of peat in test borings A and B in deposit south of East Jaffrey, N. H.

	Feet.
Hole A, northeast corner of deposit, a short distance south of wagon road: Brown well-decomposed soft plastic peat, consisting chiefly of the remains of sphagnum and heath shrubs but containing some woody roots, stumps of trees, and small spruce and cedar logs	6
Hole B, about 500 yards southwest of hole A: Peat similar in structure to that found in hole A	6½

ıposite sample (see analysis 7, p. 43) obtained by taking ntervals of 2 feet in depth in each test hole indicates that might make good fuel.

'y 2.—A deposit about 1½ miles south of East Jaffrey and one-f a mile west of Contoocook Pond, which is largely covered ;er as a consequence of the damming of Contoocook River, an average thickness of about 3 feet of peat near its eastern (See fig. 15.) The dominant living vegetation consists of nd tamarack trees, heath shrubs, the blueberry, and sphag-ıs. Some of the sphagnum is of the large leafy variety and le for use in surgical dressings. Two test borings gave the g results:

of peat in test borings C and D in deposit south of East Jaffrey, N. H.

	Feet.
e C, at roadside in center of narrow arm of bog extending ıstward toward Contoocook Pond: Brown fibrous peat, composed of the remains of sphagnum and heath shrubs	3
e D, 40 yards west of hole C: Brown fibrous peat	3

posite sample (see analysis 8, p. 43) was obtained by mixing en at intervals of 1 foot in . each hole. Although good ht be made from the peat, the s too shallow for commercial

ty 3.—A small bog about a of a mile east of Chesham shown on the map of the ɔck quadrangle published by ed States Geological Survey. ı of the bog is about 25 acres, average depth of the peat is feet. The peat is of good but the deposit is too small mercial use. A large quan-sphagnum was observed at lity.

FIGURE 15.—Map of peat deposits near East Jaffrey, Cheshire County, N. H., showing approximate position of test borings for peat.

ty 4.—Tenant Swamp, about orthwest of the railroad sta-Keene, occupies the bottom lands along Ashuelot River ensely overgrown by maple and pine trees and underbrush. ımp is shown on the map of the Keene quadrangle, published Inited States Geological Survey. A few scattered tamarack ce trees and some sphagnum moss grow in the wetter parts of

the area. Although numerous borings were made, no valuable peat was found. A shallow deposit of black muck covers the surface in some places, but there is practically no accumulation of plant remains in a large part of the area.

HILLSBOROUGH COUNTY.

Locality 5.—A bog about 1 mile southeast of Ponemah, on the north side of the Boston & Maine Railroad tracks, is probably about 150 acres in area and contains a deposit of peat 9 feet in average depth, so that it should yield approximately 270,000 short tons of air-dried peat. (See fig. 16.) The living vegetation consists chiefly of heath shrubs, sphagnum and polytrichum moss, sedges, cotton grass, and the blueberry. Small spruce trees were once numerous, but they no longer contribute notably to the formation of peat. Although sphagnum moss is present in great quantities in this locality, it is not suitable for surgical dressings. It might, however, be useful for packing material or stable litter. A series of test borings gave the following results:

FIGURE 16.—Map of peat deposits near Ponemah, Hillsborough County, N. H., showing approximate position of test borings for peat.

Thickness of peat in test borings D, E, and F, in bog southeast of Ponemah, N. H.

	Feet.
Hole D, south end of deposit, about 50 yards north of the Boston & Maine Railroad tracks: Dark-brown well-decomposed soft plastic peat, containing the remains of sphagnum, heath shrubs, and sedges, almost structureless near bottom	8½
Hole E, about 50 yards northeast of hole D along a line through center of bog: Peat similar to that in hole A, locality 6	8½
Hole F, 50 yards northeast of hole E: Peat similar to that in holes A and B, locality 6	9

A composite sample (analysis 3, p. 43) consisting of peat taken at intervals of 2 feet in depth from each hole, shows the peat to be of good quality for fuel or fertilizer. This bog could be easily drained.

Locality 6.—A bog east of Ponemah and north of the tracks of the Boston & Maine Railroad contains an open-meadow deposit consisting of pond peat overlain by built-up peat. (See fig. 16.) The bog is about 100 acres in area, and the peat is 16 feet in average thickness. The deposit appears to be capable of yielding approximately 340,000

short tons of air-dried peat and muck. The living vegetation consists chiefly of grasses, sedges, ferns, sphagnum, and polytrichum moss. A series of test borings gave the following results:

Thickness of peat in test borings A, B, and C in bog east of Ponemah, N. H.

	Feet.
Hole A, about 150 yards from west side of bog, near drainage ditch:	
Black muck	1
Brown rather fibrous grass-edge peat	3
Fibrous woody peat	½
Brown well-decomposed soft plastic peat	8½
Thoroughly decomposed peat	2½
Gray fine-grained soft pond peat, somewhat clayey	2
	17½
Hole B, about 150 yards east of hole A, near drainage ditch:	
Muck and peat similar to that in hole A	18
Hole C, about 150 yards east of hole B, near drainage ditch:	
Muck and peat similar to that in holes A and B	17

A typical sample (see analysis 4, p. 43) was obtained by mixing muck and peat taken at intervals of 2 feet in depth from each of the test holes. This sample contains a large proportion of ash, a condition that may be due to the clayey material from the bottom of the deposit or to inorganic impurities mixed with the peat in the excavation of the drainage ditch along which the test holes were made. The upper layers of the peat probably contain less ash than is shown by the analysis, and they may be suitable for fuel. This bog adjoins a railroad, is practically treeless, and could be easily drained. The peat in the upper portion of the deposit appears to be of good quality for fuel or fertilizer.

Locality 7.—A bog between the wagon road and the tracks of the Boston & Maine Railroad about 1 mile south of South Milford, which is shown on the map of the Milford quadrangle published by the United States Geological Survey, lies in an open meadow overgrown chiefly by sphagnum, cotton grass, sedges, the cranberry, and polytrichum moss. The sphagnum, much of which is of the large leafy type, suitable for surgical dressings, is dominant. A series of test borings gave the following results:

Thickness of peat and muck in test borings in bog near South Milford, N. H.

	Feet.
Hole A, near east margin of bog adjoining wagon road:	
Brown, partly decomposed peat, made up of sphagnum, grass, and sedge remains, underlain by sand	1
Hole B, west of hole A, in center of bog: Muck	1

Analysis 5 (p. 43) shows the composition of a sample obtained from the two test holes.

Locality 8.—A large swamp extends southwest from the railroad station at Greenfield for a distance of about 2 miles. Locality 8 includes an arm of this swamp about an eighth of a mile west of Greenfield. The total area of the swamp, which is shown on the map of the Peterboro quadrangle published by the United States Geological Survey, is about 640 acres, but the area of the small arm included in this locality is only about 20 acres. In earlier years the entire swamp was covered by a dense growth of trees, but the area designated locality 8 has been cleared of trees and is overgrown by grasses, sedges, sphagnum moss, and the blueberry. The sphagnum is not well developed. Several test holes were put down along a line through the center of the locality, and a representative sample was obtained. The deposit is only about 3½ feet thick where tested, and the peat as represented by analysis 6 (p. 43) is of poor quality for fuel. Although the peat is deeper in the center of the swamp, that portion is covered with so dense a growth of large trees and underbrush that it could not be profitably cleared for the production of peat.

Locality 9.—Locality 9 includes another arm of the swamp near Greenfield in which locality 8 is situated. The area consists of about 10 acres adjoining a road that extends southward from Greenfield. The living vegetation consists chiefly of sphagnum, sedges, and grasses. The average thickness of the peat, which is fibrous, silty, and unsuited for fuel, is only 2 feet.

ROCKINGHAM COUNTY.

Locality 10.—A salt marsh which adjoins Great Bay, about 1 mile northwest of Greenland, and which is shown on the map of the Dover quadrangle, published by the United States Geological Survey, covers about 640 acres. Three test holes were put down in the marsh at intervals of about 100 yards, starting about 200 yards north of the tracks of the Boston & Maine Railroad. The deposit consists of gray soft clayey material, containing the undecomposed remains of marsh grasses. A strong odor of hydrogen sulphide was noticed when each hole was put down. The average thickness of the deposit is about 9 feet. At a depth of 7 feet a thin layer of logs and pieces of wood was encountered. The wood was well decomposed and soft and was easily penetrated by the sampling rod. Analysis 1 (p. 43) shows that the deposit contains muck and is too impure for economic use.

Locality 11.—Packer Bog, about half a mile south of Greenland, which adjoins Packer Brook, is overgrown by maple, poplar, and ash trees and contains from 6 to 8 inches of black muck. A little sphagnum moss was seen, but it appeared to be unsuitable for surgical dressings. No valuable peat was found and hence no samples were taken.

Locality 12.—Great Bog, about 1 mile northeast of Greenland station, is similar in character to Packer Bog.

Locality 13.—In eight small marshes south and southeast of Portsmouth no valuable peat was found.

Locality 14.—Hampton Marsh is an extensive salt marsh along the coast of New Hampshire in the vicinity of Northampton, Hampton Beach, and Seabrook. It is several square miles in area, and the peat where tested ranges in thickness from 1 to 15 feet. The deposit is a typical New England salt marsh containing impure peat and muck. The peat is of no economic value.

Locality 15.—A deposit on the Boston & Maine Railroad near Powow Station, which is shown on the map of the Haverhill quadrangle, published by the United States Geological Survey, is covered with deep water and the peat is inaccessible without extensive drainage.

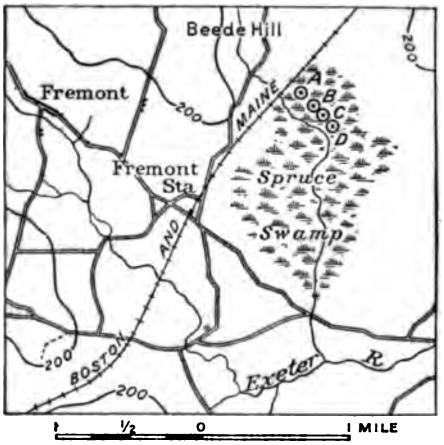

FIGURE 17.—Map of Spruce Swamp, Rockingham County, N. H., showing approximate position of test borings for peat.

Locality 16. — Spruce "Swamp," east of Fremont, is about 640 acres in area, but not more than 300 acres is covered with workable peat. (See fig. 17.) The peat where sampled is 4 to 5 feet in average thickness and is underlain by sand and clay. If there are 200 acres of peat 4 feet in average depth, the deposit should yield about 160,000 short tons of air-dried peat. The living vegetation consists of small broad-leafed trees, heath shrubs, sphagnum, and polytrichum moss, and other small plants. Much of the sphagnum moss might be used for surgical dressings. A series of test borings gave the following results:

Thickness of peat in Spruce Swamp, east of Fremont, N. H.

	Feet.
Hole A, at north end about 200 yards east of point where railroad track crosses stream flowing through bog: Brown well-decomposed soft plastic sphagnum peat, containing a few roots and pieces of wood	4
Hole B, about 100 yards southeast of hole A: Peat similar to that found in hole A	5
Hole C, about 100 yards southeast of hole B: Same character of material as that in hole B.	
Hole D, about 100 yards southeast of hole C: Peat similar to that found in hole A	4

A composite sample (analysis 2, p. 43) was obtained by combining samples of peat taken at intervals of 1 foot in depth from each of the four test holes. The deposit appears to contain peat of good quality, but it is doubtful, on account of surface conditions, whether peat could be economically produced.

OTHER COUNTIES.

Other small deposits are known in Belknap, Coos, Merrimack, Strafford, and Sullivan counties, but only a few of these contain peat of good quality for fuel or fertilizer. It is reported that peat fuel has been made and sold from a small bog near Hooksett, Merrimack County, but the deposit is not now worked.

VERMONT.

GENERAL FEATURES.

Despite the mountainous surface of a large part of Vermont, the State contains numerous widely distributed peat deposits of all types except those found in salt marshes. The deposits that offer the most promising possibilities of development are those in Bristol Pond and Shoreham Swamp, Addison County; near South Burlington, Chittenden County; Franklin, Highgate, and Richford, Franklin County; and North Hero, Isle la Motte, and South Hero, Grand Isle County. Other large areas of peat are found in these counties as well as in Orleans and Windham counties. It is estimated that 8,000,000 short tons of air-dried peat could be obtained from the deposits in Vermont.

The localities described below were tested for peat during the progress of the field work upon which this report is based. Other detailed data relating to the peat deposits of Vermont may be consulted in a report issued by the Vermont Agricultural Experiment Station.[48]

ADDISON COUNTY.

Locality 1.—A large swamp on the west side of Otter Creek, about 1 mile west of Salisbury, which is shown on the map of the Brandon quadrangle, published by the United States Geological Survey, is about 2 square miles in area and the deposit is 10 feet in average thickness. The material in the upper 3 feet and the lower 2 feet is not suitable for fuel. If the average thickness of the peat suitable for fuel is 5 feet, the bog should yield about 1,280,000 short tons of air-dried machine peat. The dominant living vegetation consists of cedar, red maple, poplar, birch, and oak trees. A series of test holes gave the following results:

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[48] The peat and muck deposits of Vermont: Vermont Agr. Exper. Sta. Bull. 165, 1912.

A. BRISTOL POND, ADDISON COUNTY, VT.

Shows floating mat of vegetation near shore and spruce trees in the background.

B. SPRUCE-SPHAGNUM BOG ON THE SHORE OF BRISTOL POND.

THE EVOLUTION OF A PEAT BOG.

Log of test borings in swamp on Otter Creek, 1 mile west of Salisbury, Vt.

	Feet.
Hole A, midway between east edge of deposit and center, beside the wagon road extending westward from Salisbury:	
Black muck and vegetable mold	3
Brown peat	7
Green soft pond peat	1
Hole B, beside wagon road at center of deposit:	
Black muck	3
Brown peat	8
Green soft pond peat	1
Hole C, at roadside midway between center and west edge of deposit:	
Black muck	3
Brown fibrous peat	4

amples were taken from each of the test holes at intervals of 2 t in depth, beginning 3 feet below the surface and extending to pond peat at bottom, and were mixed to obtain a typical specimen the workable peat. Samples of the overlying black muck were o taken. Analysis 9 (p. 49) shows the quality of the workable t and analysis 9a that of the muck.

ocality 2.—A deposit east of locality 1 in an open meadow, which s once densely wooded, is about 600 acres in area and contains t 2 feet deep overlain by about 3 feet of black muck. The land face is only a few feet above the water level in Otter Creek and herefore subject to overflow during periods of high water. The ng vegetation consists chiefly of grasses, and the peat is brown, l-decomposed, and plastic and contains considerable silt. One hole was put down midway between Otter Creek and the eastern e of the wooded portion, beside a wagon road extending westrd from Salisbury. Analysis 10 shows the composition of the ple taken from this test hole. The deposit consists chiefly of ck and peat that is too shallow and too silty to be used for fuel.

ocality 3.—A bog west of Bristol Pond (see fig. 18) contains ut 500 acres of peat that ranges in thickness from 5 to 13 feet. he average depth of the workable peat is 6 feet the deposit should ld 600,000 short tons of air-dried peat. This locality is a typical arack-spruce-sphagnum bog formed on the western shore of istol Pond, the remnant of a large lake. The dominant vegetan consists of tamarack, spruce, and cedar trees, shrubs of the th family, and sphagnum moss. Sedges, grasses, and ferns are o abundant. The floating mat of vegetation near the shore of istol Pond indicates the manner in which the outlying bog was med. (See Pl. XIV, *A* and *B*.) From the surface to a depth of o 6 feet the peat is made up of dark-brown to reddish-brown ous, slightly decomposed remains of sphagnum moss. The under-

lying peat is soft, plastic, and well decomposed. Two test holes gave the following results:

Logs of test borings in bog west of Bristol Pond, Addison County, Vt.

	Feet.
Hole A, midway between west central margin of pond and west edge of bog:	
Dark-brown fibrous sphagnum peat	6
Greenish soft pond peat	7
Hole B, one-fourth of a mile south of hole A:	
Dark-brown fibrous sphagnum peat	5
Greenish soft pond peat	7

Analysis 11 (p. 49) represents a composite sample from the upper part of the deposit, which contains brown fibrous sphagnum peat. It indicates that this peat is suitable for fuel or fertilizer. Analysis 11a shows that the underlying pond peat contains too much ash for use as fuel.

FIGURE 18.—Map of peat bogs near Bristol Pond and Pond Brook, Addison County, Vt., showing approximate position of test borings for peat.

Locality 4.—A bog south of Bristol Pond (see fig. 18) contains peat similar to that in the bog west of Bristol Pond at locality 3, but not so deep. Holes C and D, put down near the south shore of the pond, gave the following results:

Log of test borings in bog south of Bristol Pond, Addison County, Vt.

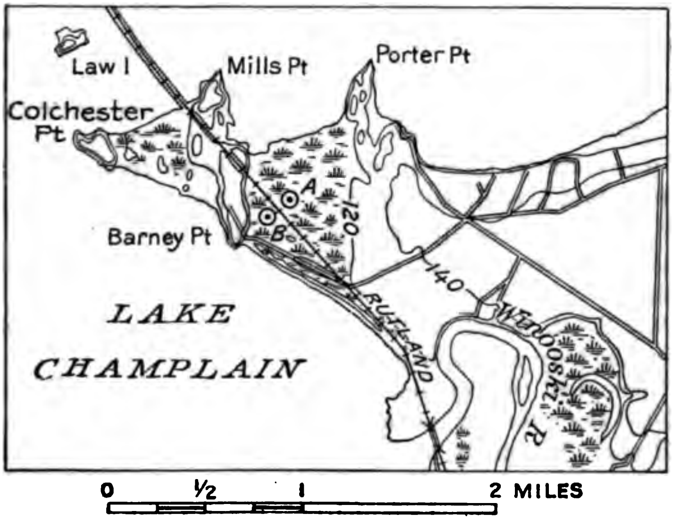
	Feet.
Brown fibrous spnagnum peat	5
Greenish soft fine-grained pond peat	3

Analysis 12 (p. 49) shows the character of a composite sample obtained by mixing peat taken from these borings. It shows that the peat may be valuable for fuel or fertilizer. Although the Bristol bog is one of the largest and best peat deposits in Vermont, it is not very well situated with respect to transportation facilities

l market and would be difficult to drain. Sphagnum moss, some which is suitable for surgical use, is very abundant in this locality.

Locality 5.—A bog about 1 mile northeast of East Monkton (see . 18) contains a deposit which was not tested, but it is reported to ntain peat 6 feet deep similar in character to that which surrounds e Bristol Pond. The area of this deposit is about 160 acres, and the average thickness of the peat is 6 feet the deposit is capable yielding approximately 192,000 short tons of air-dried peat.

Locality 6.—A bog about 2 miles east of Monkton and 1 mile north East Monkton (see fig. 18) contains about 250 acres of peat, which reported to be 5 feet deep and to be similar in quality to that ich surrounds the Bristol Pond. If the average thickness is 5 et the bog should yield about 250,000 short tons of air-dried peat.



URE 19.—Map of peat deposit southwest of Porter Point, Chittenden County, Vt., showing approximate position of test borings for peat.

CHITTENDEN COUNTY.

Locality 7.—A marsh about 1 mile south of Malletts Bay and 5 iles north of Burlington, which is shown on the map of the Milton adrangle, published by the United States Geological Survey, forms open grassy meadow, about 640 acres in area, used for grazing. e surface is covered with black muck from 1 to 3 feet deep, but no luable peat was found.

Locality 8.—A deposit near Porter Point, about 7 miles northwest Burlington (see fig. 19), which is crossed by the tracks of the utland Railroad and is skirted on its south side by a wagon road, as formed by the filling of an arm of Lake Champlain. It is

about 160 acres in area and 12 feet in average thickness and should yield approximately 416,000 short tons of air-dried peat. The living vegetation consists chiefly of tamarack, black spruce, and cedar trees, and heath shrubs, ferns, grasses, and sedges. The peat varies in texture from fibrous to plastic and is made up chiefly of the remains of sphagnum, heath shrubs, grasses, and sedges. Two test holes gave the following results:

Logs of test borings in bog near Porter Point, about 7 miles northwest of Burlington, Vt.

	Feet.
Hole A, in center of deposit, about 15 yards east of railroad track:	
Fibrous brown moss and grass peat	8
Well-decomposed to plastic pond peat	5
Hole B, opposite hole A, about 15 yards west of railroad track:	
Fibrous brown peat	8
Soft plastic fine-grained pond peat	5

Peat was taken at intervals of 2 feet in depth from each hole and mixed to obtain a composite sample. Analysis 13 (p. 49) gives the composition of this sample and shows that the peat is low in ash and high in nitrogen and therefore might be used for fuel or fertilizer.

Locality 9.—A marsh at the mouth of Lamoille River, which is shown on the map of the Milton quadrangle published by the United States Geological Survey and which is about 800 acres in area, was formed by the overflow of water from Lake Champlain and Lamoille River. The depth of the water ranges from 1 to 3 feet during most of the year. Cat-tails, reeds, grasses, and amphibious sedges are the dominant forms of plant life. Black muck from 1 to 3 feet thick was found. Analysis 14 (p. 49) gives the composition of a sample of this muck and shows that, although valueless for fuel, it may be of some value in agriculture.

FRANKLIN COUNTY.

Locality 10.—A large marsh and swamp about 2 miles southeast of Lakewood is shown on a map of the St. Albans quadrangle published by the United States Geological Survey. The margin of the deposit is overgrown by trees, and the interior is a large open marsh, covered with standing water from 2 to 5 feet deep. The marginal vegetation consists chiefly of red maple trees, and the open marsh is overgrown by cat-tails, sedges, and grasses. The outer forested zone contains no valuable peat. The peat in the open marsh, which is about 500 acres in area, was inaccessible at the time of the writer's visit, but the area is said to contain deep peat of good quality. If the average thickness of the peat in this area is 6 feet, the deposit

should yield 600,000 short tons of air-dried peat. As drainage would be difficult the deposit is not a promising one for the production of peat.

Locality 11.—A swamp and marsh at locality 11 on the east side of Missisquoi River contains no peat in the outer zone, but the interior was not tested because of excessive surface water.

Locality 12.—A deposit on the Willard farm, about 3 miles from Franklin, which is about 50 acres in area, has been used by John Webster, of Franklin, Vt., for the production of peat fuel. In a report by the Vermont Agricultural Experiment Station[49] the general features of the deposit and of Webster's early experiments are described substantially as follows:

> As indicated by the excavation the peat is black in the upper layers, brown in the center, and dark brown at the bottom. The deposit is about 6 feet deep and overlies a bed of shell "marl." The drainage ditches, which were 7 to 8 feet wide and spaced at intervals of a few rods, were made by Webster in return for the peat excavated. It was found that when the peat was disintegrated and molded, it dried much sooner than cut peat. The first year he sold $50 worth of peat fuel, but the next year he was unable to market this quantity because his customers found that the ash pan in the wood stoves used by them was not large enough to hold the ashes that accumulated in even half a day.

The following analysis shows the composition of the peat of this deposit:

Analysis of moisture-free sample of peat from deposit near Franklin, Vt.[50]

Fixed carbon and volatile matter	88.41
Ash	11.59
Carbon	51.93
Hydrogen	4.92
Oxygen and sulphur	29.46
Nitrogen	2.10
Heating value:	
Calories	4,977
British thermal units	8,959

GRAND ISLE COUNTY.

Locality 13.—A swamp that extends from South Hero about 1 mile southward along the Rutland Railroad (see fig. 20) is overgrown by maple, elm, and oak trees. Although the surface is covered by about 1 foot of black muck, the area appears to contain no valuable peat.

Locality 14.—Pearl Swamp, which extends about a mile southward from Grand Isle station (see fig. 20), is about 500 acres in area and is overgrown by maple, elm, butternut, and other trees. Although there is from 6 to 18 inches of black muck on the surface there

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[49] Hills, J. L., and Hollister, F. M., The peat and muck deposits of Vermont: Vermont Agr. Exper. Sta. Bull. 165, pp. 186–187, 1912.

[50] Hills, J. L., and Hollister, F. M., op. cit., p. 209.

appears to be no valuable peat in this swamp. Analysis 15 (p. 49 shows the quality of the muck.

Locality 25.—A swamp which extends a mile northward fro North Hero station is densely overgrown by maple trees and ap pears to contain no peat of commercial value.

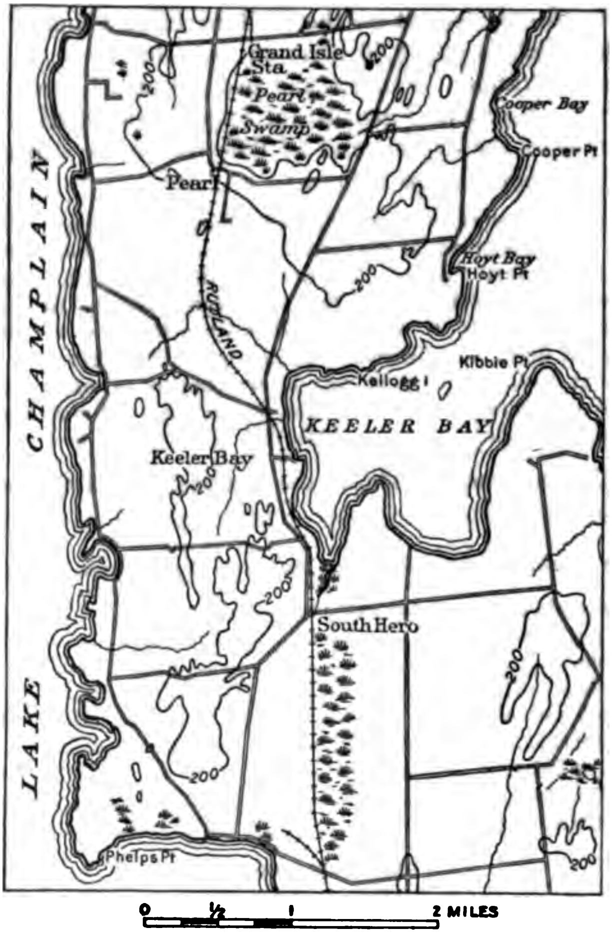

FIGURE 20.—Map showing swamps near South Hero and Grand Isle station, Grand County, Vt.

Locality 16.—A large sphagnum-spruce bog that extends nor ward and southward from Isle La Motte station (see fig. 21) c tains a deposit of peat about 1,000 acres in area and 11 feet in av age thickness, which should be capable of yielding about 2,200, short tons of peat. The peat, which is composed chiefly of the mains of sphagnum, heath shrubs, sedges, and grasses, is well composed, plastic, and of homogeneous texture except the up layer, which is fibrous. The dominant vegetation consists of spr

l tamarack trees, heath shrubs, and sphagnum. Much of the iagnum is suitable for surgical use. A series of test borings re the following results:

Logs of test borings in bog near Isle La Motte station, Vt.

	Feet.
Hole A, 100 yards west of east edge of deposit, on south side of road:	
Brown fibrous sphagnum moss, slightly decomposed	2
Brown fibrous sphagnum peat	2
Dark-brown well-decomposed, soft plastic peat	5
Hole B, halfway across bog near roadside:	
Brown fibrous sphagnum moss	2
Brown fibrous sphagnum peat	2
Dark-brown well-decomposed, soft plastic peat	6
Hole C, near roadside, 100 yards west of hole B:	
Brown fibrous sphagnum moss	2
Dark-brown sphagnum peat	2
Dark-brown well-decomposed soft plastic peat	6
Light-brown plastic grass-sedge peat	5

Analysis 16 (p. 49), which shows the character of a composite nple of peat taken from these holes, indicates that the peat is good quality. The Isle La otte bog is the largest and best at deposit in Vermont, is well ated, and could be readily ained.

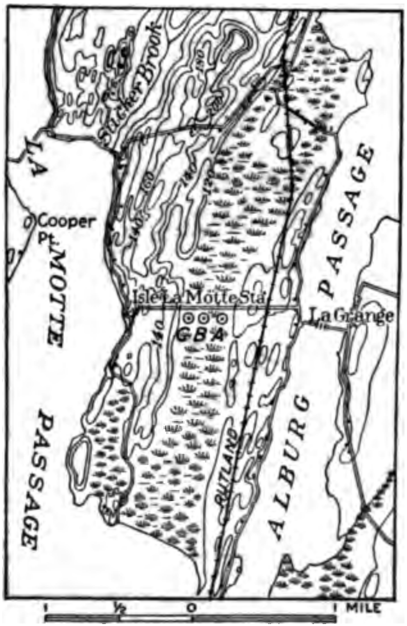

FIGURE 21.—Map of bog near Isle La Motte station, Grand Isle County, Vt., showing approximate position of test borings for peat.

Locality 17.—A swamp about miles south of Alburg (see fig.) occupies a flat, undrained area it is densely overgrown by ma- and elm trees. There is no luable peat in the swamp, ugh the surface consists of ck muck. If drained and ared the land might be of icultural value.

Locality 18.—A swamp about 000 acres in area begins about nile northwest of Alburg and ends westward along the shore Lake Champlain to Wind- l Point and Kelly Bay. (See 22.) This swamp, which skirted on the south by the cks of the Rutland Rail- d, is densely overgrown by maple trees. It appears to contain peat.

Locality 19.—A deposit about 1½ miles east of Alburg (see fig. 22) is about half a mile wide and 4 miles long and extends along both sides of Mud Creek from its mouth at Ransoms Bay, northward into Canada. It is crossed by the tracks of the Central Vermont Railway about a mile north of the mouth of Mud Creek. The area is overgrown by cat-tails and trees and is frequently flooded by Mud Creek. The peat is dark brown and well decomposed and consists chiefly of the remains of marsh grasses. A series of test borings gave the following results:

Logs of test borings in deposit 1½ miles east of Alburg, Vt.

	Feet.
Hole A, 50 yards north of railroad tracks and 100 yards west of creek: Brown silty well-decomposed peat, overlain by 6 inches of black muck and underlain by clay	5
Hole B, 50 yards north of railroad track and 100 yards east of creek: Peat similar in character to that found in hole A	5

A composite sample was obtained by mixing peat taken at intervals of 1 foot in depth from both holes. Analysis 17 (p. 49) gives the composition of this sample and shows the peat to be low in ash and high in nitrogen and therefore to be well adapted for use either as fuel or fertilizer.

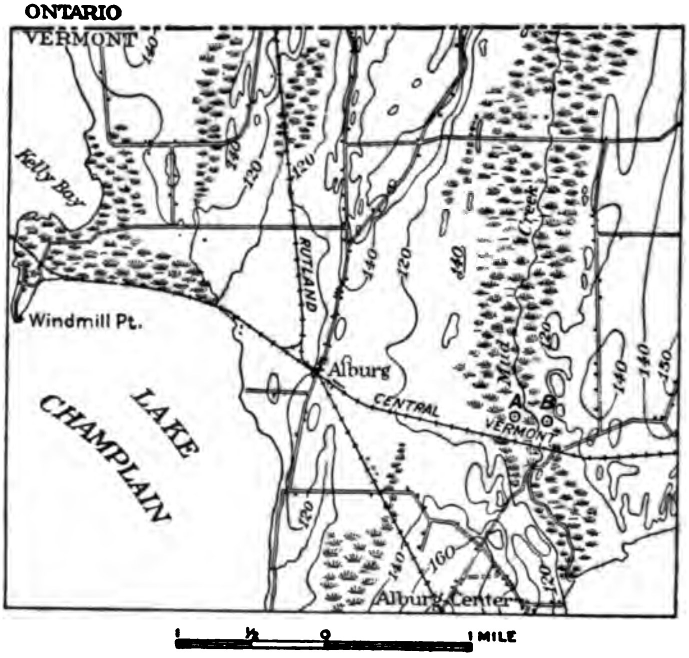

FIGURE 22.—Map of swamp and marsh near Alburg and Kelly Bay, Grand Isle County, Vt., showing approximate position of test borings for peat.

RUTLAND COUNTY.

Locality 20.—A spruce swamp about a mile southwest of Fair Haven is shown on the map of the Whitehall quadrangle published by the United States Geological Survey. The swamp is covered with a dense growth of spruce, tamarack, and cedar trees and scattered maples, alders, and willows. There is no valuable peat in this locality, and the black muck on the surface, which is only a few inches thick, is underlain by sand.

Locality 21.—A swamp east of Fair Haven and north of Castleton River occupies the bottom lands of the river and is therefore annually flooded by it. Maple is the predominant growth. There is no peat in this locality.

Locality 22.—Brandon Swamp, which is about 2 miles northwest of Brandon, between Otter Creek and the tracks of the Rutland Railroad, is shown on the map of the Brandon quadrangle published by the United States Geological Survey. A dense growth of maple, poplar, and birch trees covers the area. No valuable peat occurs in this locality.

MASSACHUSETTS.

GENERAL FEATURES.

Massachusetts possesses a larger quantity of valuable peat than any other New England State except Maine. The largest and best deposits are those in Essex, Middlesex, and Norfolk counties, the most notable being those near Norwood, East Lexington, Shirley, Littleton, Carlisle, Lawrence, Bedford, and Boston. Small cranberry bogs also occur in Plymouth County and in the Cape Cod region, and salt marshes abound along the coast, but the peat in these areas is of little value. Aside from the salt marshes, which were formed by coastal subsidence and wave action, the peat deposits of Massachusetts originated in glacial depressions and may be placed in the three classes described on pages 9 and 10. The most typical filled-basin deposits are found in the western part of Middlesex County and the eastern part of Worcester County. The Great Cedar Swamp near Taunton, the meadows near Norwood, and the marshes adjoining Charles River near Boston are the best-developed built-up deposits. The deposits in Massachusetts are estimated to be capable of yielding 12,000,000 short tons of air-dried peat. The localities described below contain the largest and most accessible deposits in the State. Small and comparatively inaccessible bogs are well distributed throughout the State, but, though valuable for local use, they are of little commercial importance.

BERKSHIRE COUNTY.

Locality 1.—A deposit about 3 miles north of North Adams, which is owned by George W. Hall, is shown on the map of the Greylock

quadrangle, published by the United States Geological Survey. It is said to be about 25 acres in area and from 6 to more than 25 feet in depth and has been partly cleared. The peat, which is of good quality, is being sold locally at $10 a ton. The deposit was not visited by the writer, but information and samples were supplied by the owner. Analysis 48 shows that the percentage of ash is only 9.14 and that of nitrogen 2.62.

ESSEX AND SUFFOLK COUNTIES.

Locality 2.—Salt marshes near Revere Beach, adjoining the mouth of Saugus and Pines rivers (see fig. 23), are several square miles in area and contain muck about 10 feet in average depth. The surface of these deposits, which were formed from salt-marsh grasses, lies at about high-tide level. The dominant vegetation consists of salt-marsh grasses. The muck is very fibrous and contains a large proportion of clay and silt. A series of test holes gave the following results:

FIGURE 23.—Map of salt marshes near Revere Beach, Essex and Suffolk counties, Mass., showing approximate position of test borings for peat.

Logs of test holes in salt marshes near Revere Beach, Mass.

	Feet.
Hole A:	
Brown fibrous, spongy muck, containing undecomposed plant remains	3
Brown soft plastic silty muck	5
Hole B:	
Brown very fibrous, spongy muck, containing undecomposed plant remains	3
Brown soft plastic silty muck	5
Grayish clayey plastic muck	2

Hole C:	Feet.
Brown very fibrous, spongy muck, containing undecomposed plant remains	3
Brown soft plastic silty muck	5
Grayish clayey plastic muck	4
Holes D, E, and F: Muck similar in character and depth to that found in holes A, B, and C.	

A composite sample (see analysis 45, p. 34) obtained by taking ıck at intervals of 2 feet in depth from each of the test holes ow the general chemical composition of the deposit. Analysis a (p. 34) shows the composition of the upper 3 feet.

Locality 3.—Wenham Swamp, in Topsfield, Wenham, and Hamil- n, extends along both shores of Ipswich River. It is shown on e map of the Salem quadrangle published by the United States ological Survey. Large elm, poplar, and maple trees are the minant plant forms. About 500 res in the center of the swamp is erlain by peat, the average thick- ss of which is about 8 feet. This at is black, well decomposed, fine ained, soft, and plastic, and is made chiefly of the remains of trees. uried twigs and pieces of wood are mmon throughout the deposit. A mposite sample (see analysis 47, 34) was obtained by mixing peat om the different test holes. Accord- g to the analysis, it would not make od fuel.

FIGURE 24.—Map of peat deposit near Mystic Pond, Essex County, Mass., showing approximate position of test borings for peat.

Locality 4.—A deposit near Mystic ond, about a mile west of Methuen d 3 miles northwest of Lawrence ee fig. 24), is about 200 acres in area and 6 feet in average depth. It ould yield approximately 240,000 short tons of air-dried peat. The rface of the deposit is overgrown by grasses, cat-tails, reeds, and dges and willow, alder, and poplar trees. The peat is of the built-up pe. A series of test holes gave the following results:

Logs of test borings in deposit near Mystic Pond, west of Methuen, Mass.

Hole A:	Feet.
Dark-brown impure peat and black muck	½
Brown fibrous peat	2½
Brown well-decomposed plastic peat	5
Holes B and C: Peat similar in character and depth to that in hole A.	
Hole D: Peat similar in character to that in hole A	5

The black muck on the surface is ascribed to the ash resulting from the destruction several years ago by fire of the upper layer of the peat. No sample of this peat was analyzed. The deposit could be readily cleared and drained, and the peat might be used locally for fuel or fertilizer.

MIDDLESEX COUNTY.

Locality 5.—About 1½ miles north of Littleton station and 1 mile southeast of Spectacle Pond (see fig. 25) there is a typical sphagnum-heath bog 100 acres in area. The vegetation consists chiefly of heath shrubs, sphagnum moss, and tamarack trees. The bottom of the deposit could not be reached with a 15-foot sounding rod. It is estimated that this deposit would yield at least 300,000 short tons of air-dried peat. A series of test holes gave the following results:

Logs of test borings in bog north of Littleton station, Mass.

	Feet.
Hole A, near north edge of bog on a north-south line through center:	
Fibrous mat of sphagnum moss and undecomposed heath shrubs	1
Brown fibrous peat, consisting chiefly of the remains of sphagnum and heath shrubs	5
Brown well-decomposed peat	9
Holes B, C, D, and E, spaced at intervals of a quarter of a mile on north-south line: Same kind of material as that obtained in hole A.	

A composite sample (see analysis 26, p. 34) of the peat in this bog was obtained by mixing peat taken at intervals of 2 feet in depth from each of the test holes. The peat seems to be of excellent quality for fuel or fertilizer. The ash content (4.04 per cent) is unusually low. Large quantities of sphagnum moss, some of which is suitable for surgical use, could be obtained at this locality.

Locality 6.—A typical cat-tail marsh about a mile south of Littleton station, adjoining the south end of Mill Pond (see fig. 25), is about 100 acres in area, and the average depth of the deposit is 4 feet. A series of test holes gave the following results:

Logs of test borings in marsh south of Littleton station, Mass.

	Feet.
Hole F, about 25 yards west of the track of the Boston & Maine Railroad, on an east-west line across the marsh a short distance south of its center:	
Soft black muck	½
Dark-brown well-decomposed plastic peat	3½
Hole G, about 100 yards west of hole F: Same kind of material as that obtained in hole F.	
Hole H, about 100 yards west of hole G, near wagon road: Same kind of material as that obtained in hole F.	

A composite sample (see analysis 27, p. 34) was obtained by mixing muck and peat taken at intervals of 1 foot in depth from each of the

oles. According to the analysis the deposit is too impure for s fuel, but the unsatisfactory character of the sample is believed due to the upper layer of muck. If this marsh were well ed the peat could be used locally for fuel. It would be neces- however, to strip off first the top layer of muck. Farmers in locality are reported to have used peat from this deposit in er years. Part of the deposit has been ed since the last peat was cut. The deposit probably thicker at that time. The muck e surface may have been formed by ash re- ng from the fire.

FIGURE 25.—Map of peat deposits near Littleton and North Littleton stations, Middlesex County, Mass., showing approximate position of test borings for peat.

cality 7.—A swamp adjoining Beaver Brook, t a quarter of a mile west of locality 6 (see 25), is about 100 acres in area, is heavily ted, and contains black muck. No valuable was found.

cality 8.—A deposit north of Duck and p ponds, about 2 miles southeast of Groton, not examined but is reported to contain peat.

cality 9.—A peat meadow adjoining Meadow k, about 2 miles south of Lowell (see Pl. *B*, p. 186), which is skirted on the west and h by the Boston & Maine Railroad, is shown e map of the Lowell quadrangle, published he United States Geological Survey. The sit is about 400 acres in area and 4 feet in age thickness and should yield approximately 00 short tons of air-dried peat. The living tation consists chiefly of grasses and sedges. peat is firm and well decomposed and is red by black muck from 6 to 12 inches thick. muck may have been formed either by the concentration he ash in the peat by fire or by the silt and sand washed adjacent streams. A series of test borings gave the following ts:

of test borings in peat deposits on Meadow Brook, 2 miles south of Lowell, Mass.

Hole A, about 25 yards east of railroad track, near west edge of meadow:

	Feet.
Black muck	½
Brown firm, well-decomposed peat	2½

	Feet.
Hole B, about 100 yards east of hole A: Muck and peat similar in depth and texture to that in hole A.	
Hole C, about 100 yards east of hole B: Muck and peat similar in texture to that in hole A	4
Hole D, about 100 yards east of hole C: Muck and peat similar in depth and texture to that in hole A.	
Hole E, about 100 yards east of hole D: Muck and peat similar in depth and texture to that in hole A.	

A composite sample (see analysis 29, p. 34) was obtained by mixing muck and peat taken at intervals of 1 foot in depth from each hole. By removing the overlying muck the peat in this deposit could be used locally as fuel.

Locality 10.—Tophet "Swamp," about a mile north of Carlisle (see fig. 26), is about 450 acres in area, and the deposit is 4 feet in average thickness. It is overgrown by plants of many species, notably sphagnum, grasses, sedges, the cranberry, shrubs, and trees. The peat, which is dark brown, firm, and well decomposed, is overlain by black muck of recent origin from 6 to 10 inches thick. A series of test borings gave the following results:

Logs of test borings in Tophet Swamp, north of Carlisle, Mass.

	Feet.
Hole A, near north edge of deposit at end of north-south line through center:	
Black muck	½
Fibrous brown peat	1
Brown well-decomposed peat, consisting of the remains of grasses and sedges	2½
Hole B, about 100 yards south of hole A: Same kind of material as that obtained in hole A.	
Hole C, about 100 yards south of hole B: Muck and peat similar in texture to that obtained in hole A	4½
Hole D, about 100 yards south of hole C: Muck and peat similar in texture to that obtained in hole A	3½

A composite sample (see analysis 30, p. 34) was obtained by mixing muck and peat taken at intervals of 1 foot in depth. The deposit seems to contain peat of excellent quality for local use as fuel or fertilizer. Some sphagnum moss suitable for surgical use occurs in the open parts of the area.

Locality 11.—A bog about 1½ miles south of South Chelmsford and 1 mile west of Tophet "Swamp" (see fig. 26) has been partly cleared at the north end and is being used for cranberry culture. The dominant vegetation formerly was sphagnum moss, heath shrubs, and tamarack trees. The area of the bog is about 300 acres, 30 or 40 acres of which is cultivated. The average thickness of the peat in the cranberry bog is more than 9 feet, but in the southern part it is only 5 feet. If the total area of workable peat is 200 acres and the average depth is 6 feet the bog should yield approximately 240,000 short tons

f air-dried peat. Several test holes were put down at points along line beginning at the north end of the cranberry bog and extending outhward. The peat is fibrous near the surface but well-decomosed, soft, and plastic beow. Analysis 31 (p. 34) hows the quality of the leep peat from the cranerry bog. The ash content s low and the fuel value is nusually high. The peat in this part of the deposit is of excellent quality for fuel. Analysis 32 (p. 34) shows the quality of the peat in the sphagnum-heath zone south of the cranberry bog. This peat is inferior in quality to that found to the north.

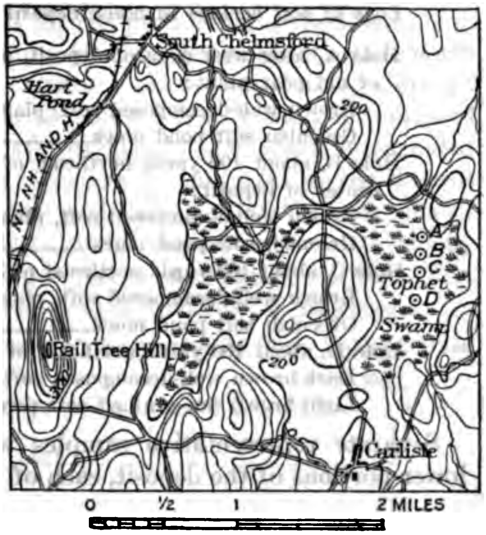

FIGURE 26.—Map of Tophet Swamp and adjoining bog, Middlesex County, Mass., showing approximate position of test borings for peat.

Locality 12.—A peat meadow adjoining Beaver Brook, about half a mile southeast of Forge Village, contains a deposit about 125 acres in area. The peat was not sampled but is reported to be about 6 feet thick and of good quality.

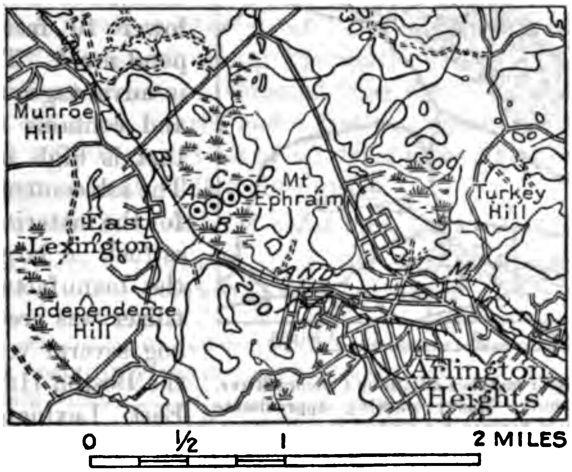

FIGURE 27.—Map of deposit near East Lexington, Middlesex County, Mass., showing approximate position of test borings for peat.

Locality 13.—A deposit near the railroad station at East Lexington, a suburb of Boston (see fig. 27), is about 100 acres in area and 13

feet in average thickness and should yield approximately 260,000 short tons of air-dried muck. A series of test borings gave the following results:

Logs of test borings in muck deposit near East Lexington, Mass.

	Feet.
Hole A, near west edge of deposit, about 50 yards northeast of old peat plant:	
Brown well-decomposed soft, plastic muck	8
Greenish soft pond muck	10
Hole B, about 100 yards northeast of hole A, on line through center of deposit:	
Brown well-decomposed soft, plastic muck	7
Greenish soft pond muck	8
Hole C, about 100 yards northeast of hole B:	
Brown well-decomposed soft, plastic muck	6
Greenish soft pond muck	4
Hole D, about 100 yards northeast of hole C:	
Dark-brown well-decomposed soft, plastic muck	3
Light-brown fine-grained soft pond muck	4

Separate representative samples were taken of the upper and lower portions of the deposit, each of which was obtained by mixing muck taken at intervals of 2 feet in depth from each hole. Analysis 34 (p. 34) shows the quality of the upper 8 to 10 feet of brown plastic muck and analysis 34a that of the lower 10 feet of green pond muck. This deposit is advantageously located and contains some muck that is high in nitrogen. The ash content is too high for the material to be used as fuel. A large plant for the manufacture of fertilizer was erected on this bog several years ago by the Boston Humus Co., of East Lexington, Mass., and was successfully operated until recently. Although the plant is not now operated, it is still in good condition and could be reopened at moderate expense. This deposit seems to be one of the best in New England for the production of peat fertilizer. It is not as large as some others in Massachusetts, but it contains good raw material and is easily accessible.

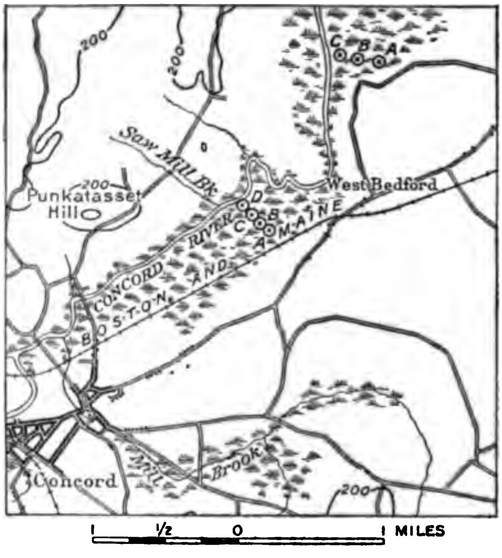

FIGURE 28.—Map of marshes adjoining Concord River, Middlesex County, Mass., showing approximate positions of test borings for peat.

Locality 14.—A muck meadow about a mile east of Bedford, which is in part being used for the cultivation of hay, was examined, but no peat was found. The meadow is covered with a shallow accumulation of black muck, which appears to be more valuable for enriching the soil of the locality than for the production of fertilizer.

Locality 15.—A marsh adjoining Concord River about a mile north of West Bedford (see fig. 28) extends southwestward along Concord and Sudbury rivers from 10 to 12 miles, but only the part north of West Bedford, consisting of approximately 500 acres, is included in this locality. The average thickness of this part of the deposit is 4 feet, and it should therefore yield about 400,000 short tons of air-dried muck and peat. The living vegetation consists chiefly of the cranberry, grasses, sedges, ferns, and small shrubs. Test holes showed material of character and thickness as follows:

Logs of test borings in marsh on Concord River north of West Bedford, Mass.

	Feet.
Hole A:	
Black muck	½
Brown fibrous peat	1
Brown well-decomposed peat	2
Hole B:	
Black muck	½
Brown fibrous peat	1½
Brown well-decomposed peat	2
Hole C:	
Black muck	½
Brown fibrous peat	1½
Brown well-decomposed peat	2½

A composite sample (analysis 35, p. 34) was obtained by mixing muck and peat taken at intervals of 1 foot in depth from each hole.

Locality 16.—A marsh along the south side of Concord River, about 1 mile northeast of Concord (see fig. 28), contains a deposit about 400 acres in area and 6 feet in average thickness, which should yield 480,000 short tons of air-dried muck and peat. A series of test borings gave the following results:

Logs of test borings in marsh on Concord River northeast of Concord, Mass.

	Feet.
Hole A, north of railroad track at south edge of swamp, six-tenths of a mile southwest of West Bedford:	
Black muck	½
Brown fibrous to well-decomposed muck	5
Hole B, about 100 yards northwest of hole A:	
Black muck	½
Brown fibrous to well-decomposed muck	5½
Hole C, about 100 yards northwest of hole B:	
Black muck	½
Brown fibrous to well-decomposed, impure peat	5½
Hole D, near Concord River, about 100 yards northwest of hole C:	
Black muck	½
Brown fibrous to well-decomposed, impure peat	5½

A composite specimen (see analysis 36, p. 34) was obtained by mixing samples from the four holes. The material in this deposit is too high in ash and too low in nitrogen for use as fuel or fertilizer.

Locality 17.—A deposit adjoining Sudbury River, about half a mile southwest of Concord. No peat was found at this locality, but about 50 acres near the river is covered with a shallow deposit of black muck.

Locality 18.—A marsh along Assabet River, north of Concord Junction, contains a deposit similar to that at locality 17.

Locality 19.—In a marsh adjoining Fort Pond Brook, about a mile northwest of West Acton, no valuable peat was found. A sample (see analysis 37, p. 34) was taken from a test hole near the center. The deposit appears to contain muck that is of no value for fuel and that is too low in nitrogen for fertilizer. The living vegetation consists chiefly of reeds, grasses, sedges, ferns, small shrubs, and the cranberry.

Locality 20.—A marsh about a mile south of West Acton, which is several hundred acres in area, contains no valuable peat. The living vegetation consists chiefly of grasses, sedges, cat-tails, the cranberry, and small ferns.

A composite sample of the deposit (see analysis 38, p. 34) was obtained by mixing material from several test holes. The deposit contains muck which can not be used for fuel.

Locality 21.—A marsh surrounding Heird Pond and adjoining Wash Brook and Sudbury River, which is several square miles in area, contains little valuable peat. Analysis 39 (p. 34) shows the character of a composite sample and indicates that the deposit consists largely of muck that is of no value for fuel or fertilizer.

Locality 22.—A marsh adjoining Sudbury River and surrounding Baldwin Pond, about 1½ miles northwest of Wayland, lies directly north of locality 21 and is of the same type. Analysis 40 (p. 34) shows the character of a composite sample and indicates that the deposit consists largely of muck that is of no value for fuel.

Locality 23.—A swamp south of Shakum Pond and west of the Milford branch of the Boston & Albany Railroad contains a deposit about 50 acres in area and 4 feet in average thickness, which should yield 40,000 short tons of air-dried peat. The dominant living vegetation consists of maple, poplar, and elm trees. Two test holes gave the following results:

Logs of test borings in swamp south of Shakum Pond, near South Framingham, Mass.

Hole A, in center of hay meadow west of car track:	Feet.
Black muck	½
Brown firm well-decomposed, plastic peat	3
Black muck	½

Hole B, about 200 yards east of hole A:	Feet.
Black muck	½
Dark-brown fibrous, woody peat	4

Analysis 41 (p. 34) shows the quality of the peat from hole A. The deposit is probably too shallow to justify the erection of a plant but could well be used for the production of cut peat.

Locality 24.—A small, deep filled-basin deposit near Bow Brook a mile southwest of Shirley contains about 3 acres of valuable peat 8 feet in average depth. A small peat plant was erected several years ago near the west edge, and an attempt was made to produce machine-peat fuel. The deposit, however, was not of sufficient size to justify such a project, and the attempt was soon abandoned. A series of test borings gave the following results:

Logs of test borings in deposit near Bow Brook, 1 mile west of Shirley, Mass.

Hole A, near east edge of deposit at site of old peat plant:	Feet.
Brown fibrous peat	1
Brown partly to thoroughly decomposed peat	13
Hole B, near center: Brown partly to thoroughly decomposed peat	10
Hole C, near west edge: Brown partly to thoroughly decomposed peat	8

A composite sample (see analysis 44, p. 34) was obtained by mixing peat taken at intervals of 2 feet in depth. The peat appears to be of fair quality for fuel or fertilizer. Although the deposit is too small to warrant the erection of a plant, enough peat could be cut to supply the farmers of the vicinity with fuel for several years.

Locality 25.—Part of the meadow that adjoins Sudbury River near the confluence of Pantry and Cold brooks contains a deposit several hundred acres in area, which should yield 480,000 short tons of air-dried peat. The dominant vegetation consists of sedges, sphagnum, and the cranberry. A test boring put down near the mouth of Cold Brook gave the following result:

Log of test boring in meadow on Sudbury River near the mouth of Cold Brook, Mass.

	Feet.
Dark-brown fibrous peat	2
Brown woody peat	5
Green fine-grained soft peat	3
Gray soft peat	1

Locality 26.—A meadow that surrounds Fair Haven Pond on Sudbury River, about 3 miles east of North Sudbury, contains a deposit about 150 acres in area and 7 feet in average thickness, which should yield approximately 210,000 short tons of air-dried peat. The vegetation consists chiefly of willow trees, shrubs, ferns, and grasses. Test

holes put down near the north and south ends of Fair Haven Pond gave the following results:

Logs of test borings in meadow surrounding Fair Haven Pond, 3 miles eas of North Sudbury, Mass.

	Feet.
Hole A, south of Fair Haven Pond, on east side of Sudbury River:	
Dark-brown fibrous to macerated woody peat	1
Reddish-brown fibrous to macerated peat	4
Dark-brown to reddish-brown somewhat woody peat	1
Dark-brown well-decomposed somewhat silty peat	2
Green fine-grained peat	2
Hole B, north end of Fair Haven Pond near east bank of Sudbury River:	
Black to gray peaty soil	2
Light-brown peat	1
Brown well-decomposed peat with woody components	2
Brown to green well-decomposed peat	2
Gray well-decomposed peat	1

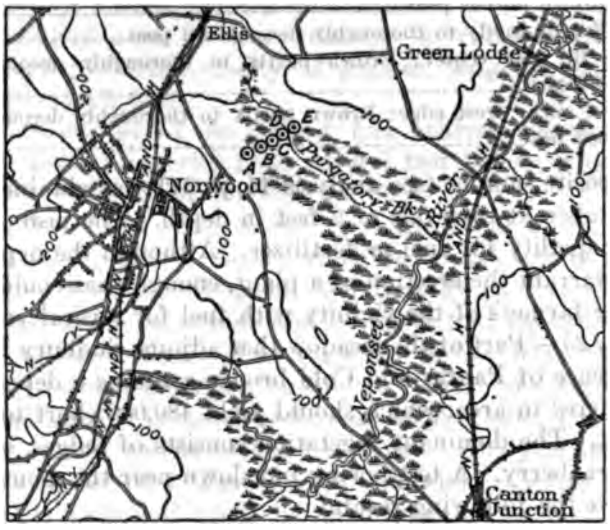

FIGURE 29.—Map of peat bog near Norwood, Norfolk County, Mass., showing approximat position of test borings for peat.

Locality 27.—A deposit in a kettle hole in glacial drift adjoinin the Wheeler farm, near Concord, was tested by a boring, which gav the following result:

Log of test boring near Wheeler farm, Concord, Mass.

	Feet.
Reddish-brown woody peat	5
Dark-brown woody peat	3
Red to brown coarsely fibrous peat	5
Coarsely fibrous, matted, leafy peat	4
Fine-grained peat, composed chiefly of débris of aquatic plants	3

NORFOLK COUNTY.

Locality 28.—A large meadow bog that adjoins Purgatory Brook about 1 mile east of Norwood (see fig. 29) contains a deposit about 600 acres in area and 10 feet in average thickness, which should yield approximately 1,200,000 short tons of air-dried peat. It extends southeastward from Norwood to the mouth of the brook, where it connects with the marsh on Neponset River. Peat fuel and fertilizer have been produced at this locality since 1918. The deposit is of the built-up type, and the dominant vegetation consists of grasses, sedges, ferns, sphagnum moss, heath shrubs, and the cranberry. The peat is relatively homogeneous and varies from dark brown to yellowish brown. Test holes put down in the deposit gave the following results:

Logs of test borings in bog on Purgatory Brook, about 1 mile east of Norwood, Mass.

	Feet.
Hole A, near south edge of bog at site of peat-fuel plant:	
Brown fibrous peat	1
Brown well-decomposed, plastic peat	6½
Hole B, about 100 yards northeast of hole A:	
Brown fibrous peat	1
Brown well-decomposed, plastic peat	8½
Hole C, about 100 yards northeast of hole B:	
Brown fibrous peat	1
Brown well-decomposed, plastic peat	9
Hole D, about 100 yards northeast of hole C:	
Brown fibrous peat	1
Brown well-decomposed, plastic peat	9
Hole E, about 100 yards northeast of hole D on north side of Purgatory Brook:	
Brown fibrous peat	1
Brown well-decomposed, plastic peat	9

A composite sample (see analysis 42, p. 34) was obtained by mixing peat taken at intervals of 2 feet in depth from each hole. The ash content is low, and the fuel value and nitrogen content are well above the average. The peat therefore seems to be of good quality for fuel or fertilizer. Analysis 42a (p. 34) shows the quality of a sample obtained from a stock pile of peat excavated for the production of fuel. Analysis 42b (p. 34) shows the composition of a sample of finished peat fuel manufactured in an experimental machine.

A part of this deposit has been leased by Peat Coal (Ltd.), of Boston, Mass., and a fuel plant was being erected when the peat was sampled. In the process selected the peat is taken from the bog by a screw excavator mounted on a dredge and transported by overhead conveyors or scows to the plant, which has a capacity of 300 to 500 short tons of peat a day. At the plant the peat is fed to a macerator, which thoroughly disintegrates and works it into a plastic mass.

About 50 per cent of the moisture is then removed by artificial drying and 30 per cent by air-drying. The company proposes to market the peat in the form of cylindrical briquets.

At the time the plant was visited good peat fuel was being produced by a small, simple machine and stored for use in the operation of the larger plant then under construction. Parts of the bog had been subleased to local residents, who were cutting peat for home use. This hand-cut peat was of excellent quality and indicates the possibilities of the numerous small bogs scattered throughout the State. This bog is near Boston, and little difficulty should be met in marketing fuel obtained from it.

Locality 29.—A small bog about midway between Walpole and East Walpole contains a deposit about 5 acres in area and 12 feet in average thickness, which should yield about 12,000 short tons of air-dried peat. It occupies a kettle hole and is of the typical filled-basin type. The living vegetation consists chiefly of heath shrubs, sphagnum moss, the cranberry, cotton grass, and sedges. The peat is dark brown to reddish brown, well decomposed, plastic, and of homogeneous texture. It is free from roots, logs, and pieces of wood and is well adapted to the manufacture of machine-peat fuel. Three test holes sunk on a line through the center of the bog gave the following results:

Logs of test borings in bog between Walpole and East Walpole, Mass.

	Feet.
Hole A, near north edge:	
Brown fibrous peat	2
Brown well-decomposed, soft, plastic peat	10
Greenish soft pond peat	3
Hole B, in center:	
Brown fibrous peat	2
Brown well-decomposed, soft, plastic peat	10
Hole C, near south edge:	
Brown fibrous peat	2
Brown well-decomposed, soft, plastic peat	8

A composite sample (analysis 43, p. 34) was obtained by mixing peat taken at intervals of 2 feet in depth from each hole. The deposit contains peat of good quality for fuel.

Several years ago Philip Allen, of Walpole, Mass., the owner of the bog, undertook the production of machine-peat fuel, but the project was abandoned. Although the peat is suitable for fuel, the deposit is too small for commercial use. However, a substantial quantity of peat could be cut and used by local residents.

Locality 30.—Adjoining the western shore of Charles River southwest of West Roxbury there is a typical river marsh that has been formed in a river valley subject to frequent overflow. (See fig. 30.) The living vegetation consists chiefly of grasses and sedges. A series

of test holes was put down, but no valuable peat was found. Analyses 46 and 46a (p. 34) show the composition of composite samples obtained from these holes and indicate that the deposit consists largely of muck.

Locality 31.—A marsh that adjoins the western shore of Charles River north of Dedham Island and east of Needham (see fig. 30) contains a deposit similar in physical and chemical characteristics to that in Locality 32.

Locality 32.—An extensive marsh adjoins both shores of Neponset River and extends from Ashcroft to Canton Junction. The living vegetation consists chiefly of grasses, sedges, and shrubs. This marsh is several square miles in area and contains a deposit of muck and impure peat from 1 to 5 feet thick. Dachnowski[51] thus describes the area:

> With the exception of the part on Purgatory Brook, the most striking feature of this deposit is an extensive surface layer of diatomaceous siliceous material adjacent to the river. The deposit ranges in thickness from 6 inches to 4 feet and is derived almost wholly from microscopic plants, mainly diatoms, which float freely in the quiet waters of ponds and rivers. Throughout nearly the length of the river this layer rests on older beds of peaty material that range in thickness from 1 to 5 feet. Most of this peaty material is well decomposed and fairly compact and generally rests on micaceous sand. The plant remains are derived in large part from transported organic material and from herbaceous and shrubby vegetation.

FIGURE 30.—Map of marsh adjoining Charles River west of Boston, Mass., showing approximate position of test borings for peat (A, B, C).

> Soundings in the part of the marsh that lies on Purgatory Brook indicate a bed of diatomaceous earth as a bottom layer in the deeper depressions. The overlying materials are types of fibrous and wicker-like peats. They are plant remains derived from vegetation units which appear to have succeeded each other in the formation of this deposit in response to changes in the ground-water table.

PLYMOUTH COUNTY.

Locality 33.—Great Cedar Swamp, about half a mile south of South Hanson, adjoins Monponset and Stump ponds on the north. Its location and area are shown on the map of the Abington quad-

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[51] Dachnowski, Alfred, unpublished notes.

rangle, published by the United States Geological Survey. Forest trees and underbrush which would be difficult to remove are the principal forms of plant life, and the peat therefore contains many roots, logs, and pieces of wood.

Locality 34.—A cranberry bog near Halifax is shown on the maps of the Abington and Middleboro quadrangles, published by the United States Geological Survey. A series of test holes in this bog gave the following results:[52]

Generalized log of test borings in cranberry bog near Halifax, Mass.

	Feet.
Red to dark-brown fine-grained to granular peat, containing woody matter	1
Dark-brown well-decomposed to fine-grained peat, containing charred woody matter	2
Red to dark-brown peat, containing leaf-mold and pine needles	1
Dark-brown to reddish-brown partly disintegrated, somewhat fibrous peat, containing roots, fibers, and woody matter	2
Reddish-brown fine-grained to fibrous peat, containing charred woody matter	1
Reddish-brown fibrous to matted peat, containing twigs and remains of heath shrubs	1
Brown well-decomposed to partly fibrous peat, somewhat silty, containing woody matter	1
Yellowish-brown well-decomposed peat, containing twigs, pieces of wood, and sand	1
Grayish coarse to fine, well-decomposed, stratified silty peat	1½

The living vegetation of this bog consists chiefly of sphagnum, the cranberry, and red maple and cedar trees.

Locality 35.—Great Cedar Swamp, about 4 miles northeast of Middleboro, is shown on the map of the Middleboro quadrangle, published by the United States Geological Survey. The dominant vegetation consists of red maple, hemlock, birch, cedar, and white pine trees. A series of test holes gave the following results:[52]

Logs of test borings in Great Cedar Swamp, 4 miles northeast of Middleboro, Mass.

	Feet.
Hole A, south end of swamp near west border:	
Dark-brown to reddish-brown fibrous peat, containing roots of living plants, twigs, and other vegetable matter	1
Black fibrous peat	1
Black to red fibrous to well-decomposed peat	2
Black to reddish brown partly fibrous, silty peat	1½
Hole B, east of hole A, about halfway across swamp: Dark-brown to red partly decomposed to fibrous peat, containing twigs and other woody components	1½

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[52] Dachnowski, Alfred, unpublished notes.

	Feet.
Hole C, east of hole B, about halfway between middle and east edge of swamp:	
Dark-brown disintegrated to fibrous peat, containing twigs and woody components	1
Black fine-grained peat	1
Black well-decomposed fine-grained peat	1
Hole D, east of hole C, south end of swamp near east margin:	
Reddish-brown to black fine-grained peat	2
Black well-disintegrated peat, somewhat silty	2
Hole E, near center of swamp:	
Dark-brown fibrous to disintegrated peat, containing twigs and woody components	1
Reddish-brown fibrous to disintegrated, plastic peat	1
Dark-brown well-decomposed peat	1
Red to dark-brown fine-grained peat, containing woody matter	1
Dark-brown well-decomposed peat	1½
Hole F, midway between hole E and east edge of swamp: Same character of material as that obtained in hole E.	
Hole G, east of hole F, near east margin of swamp: Dark-brown fibrous to disintegrated peat, containing woody matter	2½

WORCESTER COUNTY.

Locality 36.—Great Swamp, between Dunn Brook and East Brookfield River (see fig. 31), is about 350 acres in area and contains a deposit of peat 3½ feet in average thickness, which should yield approximately 45,000 short tons of air-dried peat. It is thickly wooded with red maple, elm, alder, and other broad-leaved trees. A series of test oles gave the following results:

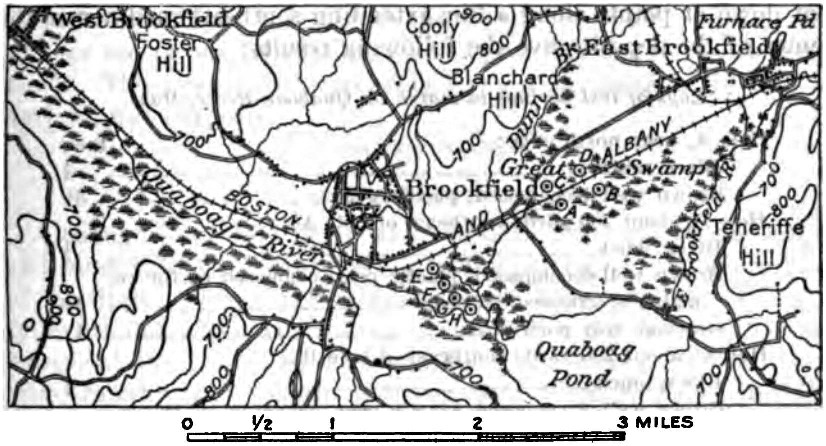

FIGURE 31.—Map of Great Swamp and marsh adjoining Quaboag River, Worcester County, Mass., showing approximate position of test borings for peat.

Logs of test borings in Great Swamp, between Dunn Brook and East Brookfield River, Mass.

	Feet.
Hole A, south of railroad track near west edge of swamp: Black impure peat and muck	1½
Hole B, south of track near center of swamp: Black sandy peat	1½
Hole C, between track and wagon road near western edge of swamp: Brown well-decomposed, plastic peat	4½
Hole D, midway between track and wagon road, near center of swamp: Brown well-decomposed, plastic peat	4

A composite sample (see analysis 62, p. 34) was obtained by mixing peat taken at intervals of 1 foot in depth from holes C and D. The peat appears to be of good quality for fuel or fertilizer. However, as the deposit would be difficult to drain and clear and the thickness is variable, it is not a promising source of peat for commercial use.

Locality 37.—A marsh extends westward along Quaboag River from Quaboag Pond to West Brookfield, a distance of about 4 miles (see fig. 31), but only the part near the pond contains good peat. The living vegetation consists chiefly of sedges, grasses, and cattails, and the peat, which is made up chiefly of the remains of these plants, is well disintegrated. The peat deposit is about 350 acres in area and 7 feet in average thickness and should yield approximately 490,000 short tons of air-dried peat. A series of test holes put down at points along a line extending southeastward across the center of the deposit gave the following results:

Logs of test borings in marsh on Quaboag River, Mass.

	Feet.
Hole A, near north edge:	
Black muck	½
Brown well-decomposed, plastic peat	3½
Hole B, about 200 yards southeast of hole A:	
Black muck	½
Brown well-decomposed, plastic peat, composed of the remains of grasses and sedges	4½
Greenish soft pond peat	4
Hole C, about 200 yards southeast of hole B:	
Black muck	½
Brown well-decomposed, plastic peat, composed of the remains of grasses and sedges	5½
Hole D, about 200 yards southeast of hole C:	
Black muck	½
Brown plastic peat, composed of the remains of grasses and sedges	7½
Greenish soft pond peat	4

A composite sample (see analysis 63, p. 34) was obtained by mixing peat taken at intervals of 2 feet in depth from each hole. The peat contains too much ash for use as fuel, but it may be of some value for agricultural purposes.

Locality 38.—A marsh about a mile southwest of Harvard station, which is shown on the map of the Groton quadrangle, published by the United States Geological Survey, is about 640 acres in area. It is overgrown by cat-tails, sedges, reeds, small willows, and trees and shrubs. The deposit is of the built-up type and occupies the bottom land of Nashua River. The peat, which is firm and well decomposed, is overlain by 6 to 12 inches of black muck and is underlain by sand. The muck was probably formed as the result of a fire many years ago. A series of test borings gave the following results:

Logs of test borings in marsh on Nashua River, near Harvard station, Mass.

	Feet.
Hole A, about 100 yards west of railroad track near edge of marsh:	
Black muck	½
Brown firm, well-decomposed peat	2½
Hole B, about 100 yards west of hole A:	
Black muck	½
Brown firm, well-decomposed peat	3½
Hole C, about 100 yards west of hole B:	
Black muck	½
Brown firm, well-decomposed peat	3½

A composite sample (see analysis 28, p. 34) was obtained by mixing peat and muck taken at intervals of 1 foot in depth from each hole. According to the analysis the deposit as a whole is too high in ash for use as fuel, but the high ash is probably due to the overlying muck. The deposit could probably be most advantageously used for agricultural purposes.

CONNECTICUT.

GENERAL FEATURES.

Although some peat is found in western Connecticut, the largest and most valuable deposits occur in the northern and eastern parts of the State. Spruce and cedar swamps, which are the predominant types of undrained land, occur at the following places: Botsford, Neversink Pond, and New Fairfield, Fairfield County; Berlin, Plantsville, Southington, South Windsor, and West Suffield, Hartford County; Benedict Pond, Chapinville, and Norfolk, Litchfield County; and Stonington, New London County. There are also many salt marshes along the coast, as well as numerous maple, ash, and elm swamps in central and eastern Connecticut. Marl underlies peat in some of the northern Connecticut deposits, notably in the tamarack swamps surrounding Twin Lakes, Litchfield County. A bed of marl 25 feet deep is reported to underlie West Twin Lake. The types of peat deposits and processes of formation in Connecticut are essentially the same as those in the other New England States.

Although Connecticut has numerous and widely distributed peat deposits they are relatively small, and the total quantity of peat that could be obtained from them is much less than the quantity available in the deposits either of Vermont or Massachusetts. The deposits in Connecticut that have been examined are capable of yielding about 1,000,000 short tons of air-dried peat. However, several of the large deposits and the numerous scattered small bogs have not been tested. Those deposits would probably yield at least 1,000,000 tons, and the total peat resources of the State would therefore amount to about 2,000,000 short tons.

The following localities were tested for peat in the progress of the field work upon which this report is based.

FAIRFIELD COUNTY.

Locality 1.—A swamp which is shown on the maps of the Danbury and Derby quadrangles, published by the United States Geological Survey, begins about a quarter of a mile south of Botsford and extends southward for about 1½ miles. The swamp is crossed by the track of the New York, New Haven & Hartford Railroad, and much of the area is owned by the railroad. The deposit covers several hundred acres, but only about 100 acres contain good peat, the average thickness of which, as indicated by test holes, is about 4 feet. The deposit is estimated to be capable of yielding about 80,000 short tons of air-dried peat. The living vegetation consists chiefly of deciduous trees, notably red maple and elm, though a few scattered spruce trees as well as some ferns and sphagnum are also present. Some of the sphagnum is of the large leafy type, suitable for surgical use. Test holes were made in different parts of the swamp, but only a few of them yielded peat. The peat, which is of the forest type, is shallow and fibrous and contains considerable woody fiber near the top but is plastic and well decomposed at a depth of 2 or 3 feet. The best peat was found in the following holes:

Logs of test borings in swamp south of Botsford, Conn.

	Feet.
Hole A, near north edge, east of railroad track: Dark-brown peat, woody near top, clayey and fine grained below	4
Hole B, beside railroad track, about one-fourth of a mile south of hole A: Brown fibrous peat, containing leaves and twigs	3½
Hole C, beside railroad track, about one-fourth of a mile south of hole B: Brown fibrous to woody peat	4
Hole D, at roadside in north central part: Brown well-decomposed peat, containing twigs, leaves, and small pieces of wood	4½

A composite sample (see analysis 57, p. 19) from a tract of about 15 acres in the area near the north edge of the swamp was obtained by mixing peat taken at intervals of 1 foot in depth from each hole.

The peat in this tract appears to be of good quality for fertilizer, but its texture makes it unsuitable for the manufacture of fuel. Analysis 58 (p. 19) gives the composition of a sample taken about half a mile south of Botsford on the west side of the New York, New Haven & Hartford Railroad track and indicates that the peat in this area is suitable for fuel or fertilizer.

HARTFORD COUNTY.

Locality 2.—A bog about 3 miles north of Cromwell, which is shown on the map of the Middletown quadrangle, published by the United States Geological Survey, is about 37 acres in area, but not all of this acreage contains workable peat. A small filled basin about 10 acres in area and 10 feet in average depth contains the best peat. The area should yield approximately 20,000 short tons of air-dried peat. The living vegetation of the 10-acre tract consists chiefly of grasses, sedges, shrubs, and sphagnum. In the surrounding woods red maple, alder, ash, and elm predominate. Except in the upper 2 feet the peat is well decomposed, plastic, and of homogeneous texture.

Logs of test borings in bog north of Cromwell, Conn.

	Feet.
Hole A, near south edge:	
Brown fibrous peat	2
Brown well-decomposed, soft plastic peat, consisting chiefly of the remains of grasses and sedges	4
Green soft clayey pond muck	4
Hole B, near center: Peat and muck similar to that in hole A	12
Hole C, north edge: Peat and muck similar to that in hole A	10

A composite sample (see analysis 59, p. 19) was obtained by mixing peat and muck taken at intervals of 2 feet in depth from each hole. The material as a whole appears to be too high in ash for use as fuel. The nitrogen content is 1.32 per cent. It may be, however, that the upper 6 feet could be used for fuel, but care should be taken to avoid the lower layers of pond muck, which are very high in ash. The deposit has been leased by A. N. Pierson, of Cromwell, Conn., who has attempted to substitute powdered peat for coal for use in heating his greenhouses.

MIDDLESEX COUNTY.

Locality 3.—A small bog about one-quarter of a mile southeast of locality 2, which is only 2 acres in area, contains a deposit of peat and muck about 3 feet deep. The living vegetation is made up largely of grasses, sedges, and sphagnum. The deposit consists of fibrous peat and muck containing much sand. It has been leased by A. N. Pierson, of Cromwell, Conn., who attempted to use the peat and muck for fuel, but the ash content was so high that the

project was unsuccessful. Analysis 60 (p. 19) gives the composition of a specimen taken from Pierson's stock pile and shows that the ash content is 58.25 per cent and the nitrogen 1.48 per cent.

Locality 4.—A marsh near the confluence of Mattabesset and Connecticut rivers, about one-fourth of a mile north of the railroad station at Middletown, which is shown on the map of the Middletown quadrangle, published by the United States Geological Survey, contains a deposit about 600 acres in area that consists of only shallow muck.

Locality 5.—Durham Meadows, which are shown on the map of the Guilford quadrangle, published by the United States Geological Survey, extend along both sides of Coginchaug River, about one-fourth of a mile west of Durham. These meadows are about 1,000 acres in area but contain no peat of commercial importance.

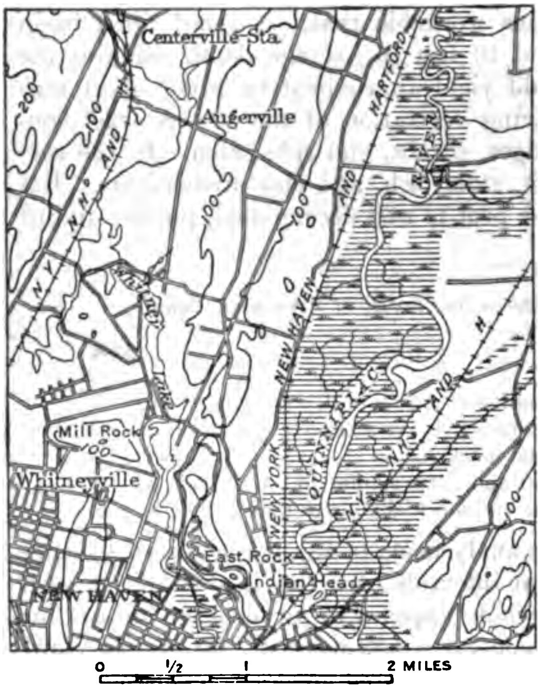

FIGURE 32.—Map of salt marsh adjoining Quinnipiac River, New Haven County, Conn.

NEW HAVEN COUNTY.

Locality 6.—A salt marsh that adjoins Quinnipiac River between North Haven and New Haven (see fig. 32) is several hundred acres in area, but only the part near the Davis brickyard, about 4 miles north of New Haven, a tract of about 300 acres, contains high-grade peat. The thickness of the deposit ranges from 4 to 7 feet, and the average depth is about 5 feet. This tract should yield approximately 300,000 short tons of air-dried peat.

The deposit as a whole consists of 2 to 3 feet of salt-marsh peat underlain by 2 or 3 feet of fresh-water peat. (See Pl. XV, *A*.) The fresh-water peat is dark brown to black, well decomposed, and plastic and contains well-preserved remains of ferns, sedges, and grasses. The salt-marsh peat is fibrous and somewhat silty. The section illustrated in part by Plate XV, *A*, was exposed by excavations for clay. Several old stumps of trees 12 inches in diameter

A. CROSS SECTION OF COMPOSITE PEAT BED NEAR NEW HAVEN, CONN.

1, Salt-marsh peat; 2, fresh-water peat; 3, contact.

B. TYPICAL PEAT MEADOW NEAR LOWELL, MASS.

and in place in the excavations at the bottom of the fresh-water eat. Specimens were taken from the exposed section, which is oneghth of a mile long, and from a hole put down a few yards from the ay pit.

Analysis 53 (p. 19) shows the composition of a combined sample f fresh-water and salt-water peat taken from the hole, and analysis 4 (p. 19) that of a sample taken from a pile of peat which had been xposed to the weather for a year. The high ash content shown in nalysis 54 is ascribed to the admixture of dust from the adjoining lay pit. Analyses 53a–d (p. 19) show the composition of samples of oth the salt-marsh and fresh-water peat collected by George E. ichols.

hickness of beds of salt-marsh and fresh-water peat in boring in marsh on Quinnipiac River, Conn., sampled for analysis.

	Feet.
Salt-marsh peat (analysis 53a)	1½
Salt-marsh peat (analysis 53b)	1
Fresh-water peat (analysis 53c)	1
Fresh-water peat (analysis 53d)	1½

Both types of peat contain an unusually large percentage of sulhur. The average nitrogen content of the salt-marsh peat exceeds per cent.

Several years ago peat from this deposit was used for fuel, but he plant has been dismantled. Much of the peat in the vicinity of he brickyard has been stripped from the land in order to obtain the nderlying clay. If an attempt is made to produce fuel from this eposit the top layer of impure, silty salt-water peat should be removed to a depth of at least 2 feet.

Locality 7.—A salt marsh about 1 mile west of Short Beach and 8 miles southeast of New Haven, which is shown on the map of the New Haven quadrangle, published by the United States Geological Survey, contains a deposit about 200 acres in area and 6 feet in verage thickness, which should be capable of yielding approximately 240,000 short tons of air-dried muck. Five test holes were made along a line 100 yards east of and parallel to an electric railway rack that crosses the marsh. Analysis 55 (p. 19) shows the composition of a composite sample taken from these holes and indicates hat the deposit is of no value for fuel or fertilizer.

Locality 8.—A deposit near New Haven, about one-fourth of a mile ast of Granniss Corner, which is shown on the map of the New Haven quadrangle, published by the United States Geological Survey, is about 75 acres in area and 6½ feet in average thickness. It is stimated that this deposit is capable of yielding 97,500 short tons of ir-dried peat.

The peat is of the built-up type and is dark brown, well decomposed, plastic, and free from woody components. A composite sample (see analysis 56, p. 19) was obtained by mixing peat taken at intervals of 1 foot in depth from test holes put down along a line through the center. Although physically suitable for fuel, the peat in this deposit is so high in ash that only low-grade fuel could be made from it.

Locality 9.—A salt marsh at the mouth of Stony Creek is crossed by the tracks of the New York, New Haven & Hartford Railroad and by a suburban electric railway. The deposit is about 200 acres in area and 5 feet in average thickness and should yield approximately 200,000 short tons of air-dried peat and muck. A series of test holes gave the following results:

Logs of test borings in salt marsh at mouth of Stony Creek, 2½ miles east of Branford, Conn.

	Feet.
Hole A, near west edge of marsh, north of electric railway tracks:	
Grayish fibrous impure silty peat	2
Brownish-gray muck, somewhat fibrous, containing undecomposed remains of marsh grasses	2
Hole B, near edge of Stony Creek, in center of marsh:	
Grayish fibrous muddy peat	3
Gray to brown fibrous muck	2
Hole C, near east edge of marsh north of car track: Peat and muck similar in depth and character to that in hole B	5

As the underlying muck is too impure to be of commercial value only the upper 2 feet of peat was sampled. A composite specimen (see analysis 61, p. 19) was taken from the sides of a small drainage ditch that crosses the marsh. The high content of ash is believed to be partly due to inorganic impurities mixed with the peat in the excavation of this ditch.

Data relating to the area, depth, and chemical composition of several other peat deposits in this county are given in the table of analyses (pp. 19–22).

RHODE ISLAND.

The most valuable peat deposits in Rhode Island occur in the fresh-water bogs and swamps of Bristol, Providence, and Washington counties. Although there are many salt marshes on the coast they contain little peat of economic value. The peat of Rhode Island is similar in origin and physical and chemical properties to that of Connecticut and other New England States. The swamps and bogs of Rhode Island are estimated to be capable of yielding 1,000,000 short tons of air-dried peat.

BRISTOL COUNTY.

Locality 1.—A deposit about half a mile west of Barrington, which is shown on the map of the Narragansett Bay quadrangle, published by the United States Geological Survey, was formerly about 300 acres in area, but the peat has been stripped from 200 acres in order to obtain the underlying clay. The average thickness of the peat in the remaining 100-acre tract is only about 2½ feet. It is dark brown to black, rather fibrous, and earthy. The deposit was originally wooded, but it has been cleared and drained. Analysis 52 (p. 49) shows that the peat is too high in ash for use as fuel and too low in nitrogen for use as fertilizer. Other deposits in Bristol County are reported to contain high-grade peat, but they were not tested.

PROVIDENCE COUNTY.

Locality 2.—A meadow adjoining Cherry Brook about a mile south of Woonsocket, which is about 200 acres in area, contains black muck and impure peat from 1 to 3½ feet deep. Four test holes were put down along a line through the center of the meadow, from which a composite sample was taken. Analysis 49 (p. 49) shows the chemical composition of this sample of the deposit, which consists largely of muck.

Locality 3.—A marsh adjoining Blackstone River between Valley Falls and Lonsdale, which is about 200 acres in area, contains only sandy muck.

Locality 4.—A swamp about 1½ miles northwest of West Greenville, which is shown on the map of the Burrillville quadrangle, published by the United States Geological Survey, contains a deposit which is about 50 acres in area and which exceeds 25 feet in maximum thickness. If the average depth is 15 feet the deposit should yield approximately 150,000 tons of air-dried peat and muck. The living vegetation consists chiefly of maple, elm, ash, and alder trees. The peat is composite in origin and ranges in texture from fibrous to plastic. Two test holes put down in the center of the swamp adjoining a road that crosses the deposit gave the following results:

Log of test borings in swamp near West Greenville, R. I.

	Feet.
Black muck	1
Black peat	1
Red to brown woody, forest peat	2
Dark-brown, well-decomposed, built-up peat	2
Yellowish-brown soft, plastic impure pond peat and muck	19+

Analysis 51 (p. 49) shows the character of a composite sample obtained from these holes and indicates that the deposit is unfit for fuel. This is probably the deepest peat deposit in Rhode Island, but it is not favorably situated for commercial use.

WASHINGTON COUNTY.

Locality 5.—A marsh adjoining Chapman Pond, about 2 miles east of Westerly, which is shown on the map of the Stonington quadrangle, published by the United States Geological Survey, is approximately 600 acres in area, but on account of high water the large tract south of the pond could not be sampled. The tract north of the pond is about 50 acres in area and contains a deposit 6 feet in average thickness, which should yield about 60,000 tons of air-dried peat. If the peat in the large area south of the pond is of the same average thickness the entire deposit contains approximately 720,000 tons of peat. The peat near the pond is of the filled-basin type, but that more remote is of the built-up type. The living vegetation consists chiefly of an inner zone of cat-tails, sedges, and grasses and an outer margin of poplar, elm, and willow trees. A series of test borings gave the following results:

Logs of test borings near Chapman Pond, Westerly, R. I.

	Feet.
Hole A, midway between the track of the New York, New Haven & Hartford Railroad and north shore of Chapman Pond:	
Brown fibrous to spongy peat	4
Dark-brown soft, well-decomposed peat	2
Hole B, about 100 yards west of hole A: Peat similar in texture and depth to that in hole A.	

A composite sample (see analysis 50, p. 49) taken from these holes shows the quality of the peat in the northern part of the deposit.

Locality 6.—Several test holes were put down in a bog about 3 miles east of the railroad station at Westerly and 1 mile east of Chapman Pond, which forms an arm of the large bog adjoining Pawcatuck River (see locality 7). These test holes were put down at intervals of about 100 feet near the railroad track that crosses the bog but failed to show peat. The deposit appears to consist of 12 to 16 inches of black muck underlain by sand.

Locality 7.—In the part of the bog that adjoins Pawcatuck River about 4 miles west of Bradford the living vegetation consists chiefly of the cranberry, heath shrubs, sphagnum, grasses, and sedges—plants that grow on typical peat bogs—but no valuable peat was found. Maple, elm, and ash trees constitute the marginal vegetation. The surface consists of a layer of muck about 2 feet deep.

Locality 8.—A swamp on Pawcatuck River about 1 mile east of locality 7, which is shown on the map of the Stonington quadrangle, published by the United States Geological Survey, is densely wooded, and in August, 1918, was covered with water from 6 to 12 inches deep. No peat of economic value was found. A deposit of undecomposed plant remains and black muck about 1 foot thick constitutes the surface layer.

ocality 9.—Indian Cedar Swamp, which is shown on the map of Charlestown quadrangle, published by the United States Geo- ical Survey, lies about 1 mile south of the railroad station at od River Junction. This swamp is about 1½ miles long and 700 es in area. Samples were taken around the margin, but on ac- nt of the surface water the interior was not tested. In the part pled only 1 foot of muck was found. The swamp is densely ested. Peat of workable depth may occur in the interior, but h extensive clearing and road building would be necessary that present value of the deposit is doubtful.

ocality 10.—Great Swamp, between West Kingston and Kenyon, ugust, 1918, was mostly flooded. Where it was examined around margin no peat of economic value was found. Deep peat is orted to occur in the interior of the swamp, but this report was confirmed.

OTHER STATES.

onditions are favorable for the formation of peat in the upper ley of Red River, in North Dakota, and in the region east of nes River, in South Dakota, but these areas were not examined for s report. Small accumulations of muck and peat have been noted Lake Marsh, Hamlin County, and Madison Lake, Lake County, Dak., but the material in these localities probably contains a large portion of inorganic impurities and may not be of workable th.

ATLANTIC COASTAL REGION.

VIRGINIA AND NORTH CAROLINA.

GENERAL FEATURES.

lthough some peat is found in the tidal flats on Potomac River, most extensive deposits in Virginia occur in the Dismal Swamp trict, which extends southward from Portsmouth into the northern nties of North Carolina. Peat also occurs throughout an area ut 50 miles wide along the coast of North Carolina from Albe- rle Sound to the northeastern boundary of South Carolina, as well in parts of the upper valleys of Roanoke, Neuse, and Cape Fear ers. The peat, which is largely of the built-up type, originated in atively flat, undrained salt marshes along the coast and in fresh- ter swamps farther inland. The deposits of Virginia and North rolina are estimated to be capable of yielding 700,000,000 short s of air-dried peat. The Dismal Swamp lies in both Virginia and rth Carolina and contains most of the peat in these States, and refore the two States are considered under one heading.

ARLINGTON AND FAIRFAX COUNTIES, VA.

There are several small undrained areas in the eastern parts of lington and Fairfax counties, Va., adjoining Potomac River.

The marshes south of Alexander Island, at the mouth of Fourmile Run, and in Hunting Creek, as well as the tidal marsh about 2 miles south of Alexandria, were examined, but only shallow bluish-gray impure peat and silty muck, consisting largely of the remains of marsh grasses, were found. These areas are illustrated on the map of Washington and vicinity, published by the United States Geological Survey. The tidal marsh south of Alexandria is nearly 2 miles in length and ranges from about one-eighth to one-half mile in width. Its surface lies below the water level of Potomac River at high tide and consequently it is usually covered with water from a few inches to about 2 feet in depth. The living vegetation consists largely of wild rice, flags, and marsh grasses. If this marsh were drained the soil would probably yield good truck crops, but it seems doubtful whether drainage would be profitable. Similar marshes occur at the mouths of numerous tributaries to Potomac River in other counties.

DISMAL SWAMP DISTRICT.

GEOGRAPHY AND GEOLOGY.

The Dismal Swamp district is in the Coastal Plain of southeastern Virginia and northeastern North Carolina. (See Pl. XVI.) It lies roughly between parallels 36° 15′ and 36° 45′ N. and meridians 76° 5′ and 76° 35′ W., and approximately includes Norfolk County and the eastern part of Nansemond County, Va., and Perquimans, Pasquotank, Camden, and Currituck counties, N. C. As the limits of the swamp depend largely upon rainfall and vegetation, as well as topography, they are rather irregular and are not sharply defined.

The swamp is traversed from Deep Creek, Va., to South Mills, N. C., by the Dismal Swamp Canal and is cut by numerous smaller canals and ditches radiating from Lake Drummond. The Norfolk Southern Railroad skirts the eastern, southern, and western parts of the swamp, and its north end is crossed by the Virginian, Seaboard Air Line, and Norfolk & Western railroads.

The total area of the Dismal Swamp is about 2,200 square miles, of which a little more than 700 square miles has been drained by the Dismal Swamp Canal and other ditches. A large part of the swamp is owned by the Roper Lumber Co., Norfolk, Va., and by the Richmond Cedar Works, Richmond, Va.

The region as a whole is but sparsely populated, and the chief industries in the reclaimed areas are lumbering and agriculture.

The peat deposits of the Dismal Swamp lie in shallow basins that originated in an extensive depression of the Columbia group of formations. During the deposition of these formations the mouth of James River was some distance southwest of its present mouth,[64]

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[64] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Norfolk folio (No. 80), pl. 1, 1902.

U. S. GEOLOGICAL SURVEY

MAP OF SOUTHEASTERN

l the sediment it laid down probably formed a bar or delta east the swamp. When the land was subsequently uplifted, the mouth the James was diverted to its present position, and between the race formed by its delta and the Nansemond escarpment there nained a large, poorly drained depression in the surface. The rmal precipitation of the region is about 52.08 inches and the aver- humidity is 73 per cent. Thus favored by topographic and cli- tic conditions, the surface was soon saturated or covered with ter and luxuriant vegetation, and it has remained in substantially same state since that time.

While the swamp was young most of the peat was formed below ter level and the deposits were largely of the filled-basin kind. ter many basins in the region were filled to the general level of surrounding country by vegetal accumulations, and much of the face water was drained off through the Dismal Swamp Canal and sidiary ditches. Thus the Green Sea, which was originally con- ted with the main morass, has been detached by the draining of intervening area. Many marginal sections have also been re- imed for agricultural use by small ditches and are no longer ampy, except in very wet weather. However, the greater part of swamp is still so poorly drained and so choked with plant owth that it is continually saturated or covered with water. The erage depth of the water is only a few inches. In the western rt the water is in places 2 feet deep, and peat is still forming ere under water. In the eastern part the water seldom stands ove ground, although in many places it keeps the surface so ghly saturated that peat is still accumulating. In the thoroughly ained sections the formation of peat has been superseded by that leaf mold.

FLORA.

The Dismal Swamp lies at the junction of the coniferous and de- uous forest regions of the eastern coast of the United States. flora comprises plants of a great number of species and is inter- ing because it shows a mingling of the northern and southern land ras. In the earlier stages of peat formation algae and mosses bably grew profusely in its shallow waters, building up de- sits of fine-grained peat, which are now found in the bottoms of basins. As the remains deposited by these plants accumulated basins became shallower, enabling the pondweeds (*Potamogeton*), water lilies (*Castalia* and *Nymphaea*), and the lake bulrush *cirpus*) to establish themselves temporarily.[55] In some of the gher parts of the morass the bog-meadow and bog-heath stages, which the *Carex* and *Andromeda-Ledum* associations predomi-

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[5] Davis, C. A., U. S. Geol. Survey Bull. 376, p. 13, 1909.

nated, may have followed in small areas. As the surficial depressions were relatively shallow, and as logs are found in nonfibrous peat at depths of 5 to 10 feet in many sections of the swamp, it is believed that deciduous and coniferous trees more or less fully superseded the other flora at an early date and contributed the greater part of the dead vegetation from which the peat deposits of the region were formed.

The present flora of the Dismal Swamp includes aquatic plants, the fern and peat-moss association, deciduous and coniferous trees, and associated undergrowth. Nearly the whole region is forested, and the plant associations are so intimate that it is difficult to delimit the distinct formations. However, the following ecologic classification, which follows roughly the classification used by Schenck in "Biologie der Wassergewächse," shows the most abundant plants that are now contributing to the formation of peat:

Aquatic plants.

Submersed:
- Utricularia spp.
- Riccia fluitans.
- Philotria canadensis.
- Sphagnum kearneyi.
- Callitriche heterophylla.
- Juncus repens.
- Isnardia palustris.

Floating on the surface:
- Spirodela polyrhiza.
- Castalia odorata.
- Nymphaea advena.

Floating on the surface:
- Nelumbo lutea.
- Potamogeton lonchites.
- Callitriche heterophylla.

Rising above the surface:
- Sparganium androcladum.
- Myriophyllum heterophyllum.
- Woodwardia virginica.
- Eriophorum virginicum.
- Decodon verticillatus.
- Limodorum tuberosum.
- Sphagnum cymbifolium.

Black gum association.

Water ash (Fraxinus caroliniana).
Rattan (Berchemia scandens).
Yellow jessamine (Gelsemium sempervirens).
Cross vine (Bignonia capreolata).
Water gum (Nyssa biflora).
Bald cypress (Taxodium distichum).
Red maple (Acer rubrum).
Cotton gum (Nyssa aquatica).

White cedar association.

Loblolly pine (Pinus taeda).
Sweet bay (Magnolia virginiana).
White cedar (Chamaecyparis thyoides).
Shrubs (Ericaceae association).
Cane (Arundinaria macrosperma).

Aquatic plants are found in nearly all the wetter parts of the swamp, notably in some of the abandoned ditches, which have been completely filled with them. However, in areas of dense shade they make little headway and are of minor importance in the formation of peat.

BLACK GUM AND BALD CYPRESS PLANT ASSOCIATION IN THE DISMAL SWAMP, VA.

Ferns and peat mosses are found in the open parts of the region. *hagnum cymbifolium* grows in the shallow water and among the pes of the *Woodwardia* in the higher parts of the peat area. The ts are usually submerged, and the stems, which range in length m 6 to 18 inches, rise above the surface.

The water gum, locally known as black gum, and white cedar or iper forest associations predominate throughout the region and tribute the greater part of the dead vegetation that is now ac- nulating. The densely forested wetter part of the morass, espe- lly the area surrounding Lake Drummond, is known as the black- n swamp. (See Pl. XVII.) It is characterized by the profuse wth of black gum and its associated undergrowth, although red ple is also abundant. Here immense quantities of peat are now umulating. The bald cypress is also still found in some parts of black-gum swamp but probably was more abundant in earlier rs. In fact, the most striking feature of the region is the weird ect presented by the cypress knees in the interior and the belt of weathered cypress stumps standing on the margin of Lake Drum- nd and hung with Spanish moss. These stumps, which have sur- ed the attacks of the weather for many years, and the numerous ll-preserved cypress logs that are encountered several feet beneath surface indicate that cypress formerly contributed much more d vegetation to the peat deposits than now.

The open, light parts of the morass, known locally as juniper mp, are largely occupied by the white-cedar association. In lier years these areas were completely forested by white cedar, now, owing in part to the work of man, many of them bear a wth of shrubs and cane.

PROPERTIES.

The two leading kinds of peat in the Dismal Swamp are known ally as "black-gum peat" and "juniper peat." The "black-gum t," which is dark brown or black, thoroughly decomposed, and atively homogeneous in structure, is found in what were formerly wetter parts of the region, especially near Lake Drummond, and rs a growth of black gum, red maple, and bald cypress. It is well mified and almost destitute of fibrous structure. When dry it aks easily, leaving lusterless fracture surfaces. "Juniper peat," ich ranges from dark to light brown in color and is rather fibrous, found in the light or open swamp and bears a growth of white ar, pine, sweet bay, shrubs, and cane. Decomposition is not far anced and the peat contains many stems, roots, and logs. On the tern margin of the swamp near the source of Northwest River re is a typical area of this material. When dry it hardens in lump m and breaks with difficulty.

The chemical composition of peat in the Dismal Swamp is shown by the analyses given in the table (p. 50). "Black-gum peat" (samples 1, 2, and 5), because of its thorough decomposition, contains more nitrogen and fixed carbon than "juniper peat" (sample 4) and therefore is less acidic. It also contains less ash and is of greater commercial value. Where the ash content exceeds 8 per cent it consists chiefly of alumina and silica in the form of clay and sand.

ASSOCIATED MARL.

Shell beds or so-called marls underlie the peat deposits at many places in nearly all the counties of the Dismal Swamp region. Although no outcropping beds were observed in the areas tested for peat, it is said that many of these strata have been penetrated by wells and extensively exposed by drainage excavations. Shells thrown upon the bank of Dismal Swamp Canal by dredges were seen near Deep Creek and Wallaceton, Va., and Lilly and Moyock, N. C. Several years ago a dredge of the Lake Drummond Canal & Water Co. in deepening the canal feeder penetrated a shell bed about midway between the source and mouth of the feeder. A large quantity of shell "marl" was thrown upon the bank at this point, but on account of the action of the dredge and of the weather since that time it is now disintegrated and mixed with sand and clay. W. C. Mansfield, who identified the following fossils collected at this locality, believes that they are of Pleistocene origin:

Venus mercenaria Linné.
Ostrea virginica Gmelin.
Arca transversa Say.

It has been said[56] that the age represented by these fossils is Pliocene, but as they are also found in the Pleistocene and underlie peat of late Pleistocene origin, it is probable that they belong to the Pleistocene series.

An estimate of the quality of shell "marl" in the Dismal Swamp region is not available, but if the material occurs in workable quantities and can be cheaply excavated, many peat areas in this region that on account of the acidity of the soil are now valueless for general farming could perhaps be economically treated with lime from these shell beds and made to yield large alkaline-soil crops.

DISTRIBUTION AND QUANTITY.

The Dismal Swamp covers approximately 2,200 square miles, of which a little more than 700 square miles has been permanently drained to a depth of 3 feet or more by Dismal Swamp Canal and smaller ditches. (See Pl. XVI.) Much of the drained land is

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[56] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Norfolk folio (No. 80), p. 3, 1902.

rmed. In the remaining 1,500 square miles peat deposits ranging depth from 1 foot to 20 feet are found. The thickest beds lie in e region east and northeast of Lake Drummond, where peat 18 feet ep was exposed by comparatively recent excavations. The peat in is area is black and low in inorganic impurities and is probably e best in the swamp. In general, the depth of the peat gradually creases toward the edge of the swamp, where the peat finally erges into the sands of the adjoining areas. The eastern border deeply indented by large tracts that have been drained, cleared, d cultivated. Some valuable peat is found in the southern and utheastern parts of the morass, but the northern and western parts ntain few deposits large enough to be of commercial importance.

The Dismal Swamp is not entirely covered with peat—in fact, not ore than half of it contains peat of commercial value. In some rts of the swamp the peat is too shallow to be worked profitably, d in others it contains so many roots, stumps, and logs that excation by present methods would be impracticable. In many areas e peat has been destroyed by forest fires. In some of the heavily rested areas peat has never formed to great depths, perhaps beuse of the presence of excessive surface water and dense shade, hich prevented the growth of shrubs, mosses, grasses, reeds, ferns, d other prolific peat-forming plants. From numerous test borings, servations made along the banks of drainage canals, and informan furnished by drainage engineers who are familiar with the amps, it is estimated that the average thickness of the peat is 7 et. On the assumption that the uncultivated area of the Dismal vamp is 1,500 square miles, that about one-half of this area is coved with peat averaging 7 feet in depth, and that the bog will eld 200 tons of dry peat per acre-foot, then the total available at in the Dismal Swamp is 672,000,000 tons.

AREAS TESTED.

Norfolk County, Va.—The best peat in the Dismal Swamp is und in Norfolk County, Va., in the territory northeast of Lake rummond. This area is close to the truck-farming section of Virnia, to which the peat could be cheaply transported by means of e Dismal Swamp Canal. As shown by the analyses (p. 50) much this peat is high in thermal value and contains relatively little h and a fair percentage of nitrogen. It could therefore be used r fuel or as a nitrogenous ingredient of commercial fertilizer.

It is reported that in 1860 a peat-fuel plant was erected near the e of hole A, described below, but that on account of economic conions which arose with the outbreak of the Civil War it was unsucsful, and the machinery was dismantled. So far as known this

is the only attempt that has ever been made to market peat from the Dismal Swamp.

As shown on Plate XVI, test borings for peat were made along the Norfolk & Western Railway, the Dismal Swamp Canal, the canal feeder, and the eastern shore of Lake Drummond. No peat of consequence was found in the region traversed by the railway, but in the other areas the test borings gave the following results:

Hole A was drilled at a point 1 mile north of Wallaceton and 300 feet east of Dismal Swamp Canal. Nonfibrous peat, ranging in color from dark brown to black, was found to a depth of 10 feet. Sample 1 was taken at a point 4 feet from the surface, and sample 2 at 6 feet. (See analyses, p. 50.)

Hole B was made on the north bank of Northwest River, 300 feet east of Dismal Swamp Canal. Here 9 feet of peat similar in physical characteristics to the specimens taken from hole A was found. Samples 3 and 4 were taken at depths of 4 and 6 feet, respectively.

Hole C was sunk to a depth of 9 feet at a point midway between Jericho Canal and the source of the feeder ditch by which water is supplied to Dismal Swamp Canal. About 8 feet of peat, underlain by white sand, was found here, but as it seemed to be similar to the material from holes A and B no sample was taken for analysis.

Hole D, in which 10 feet of peat underlain by alternate layers of white sand and blue clay was found, was made 200 feet north of the water gate in the Dismal Swamp Canal feeder. The surface layer of this peat is black and well decomposed, but the subsurface layers range in color from dark to light brown. Sample 5 was taken 4 feet below the surface.

Hole E was drilled on the bank of Dismal Swamp Canal opposite the mouth of the feeder. As the peat was rather fibrous and only 3 feet deep at this point it was not sampled for analysis.

Nansemond County, Va.—Hole F was sunk on the south side of Washington Ditch about a mile northwest of Lake Drummond, in Nansemond County. This boring, as well as four others at intervals of three-quarters of a mile northwestward along this ditch, failed to show peat in commercial quantities. From 1 to 3 feet of muck was found, and sample 6, consisting of a composite mixture of material from the surface to a depth of 3 feet, was taken in order to show its character. The absence of peat in this area may be due to the dense stand of mature timber and the excessive quantity of water that cover it, preventing the growth of shrubs, mosses, and other prolific peat-forming plants.

Currituck County, N. C.—Hole J, in Currituck County, N. C., was put down on the north side of Old Swampy Road about 800 yards northeast of the line between Currituck and Camden counties. It penetrated 7 feet of black, thoroughly decomposed peat. The

area of this deposit is approximately 100 square miles, and for the most part the material is of the built-up type, though the deposit contains some filled-basin peat. As shown by the analyses (p. 50), the peat is unusually high in thermal value, contains little ash and a relatively high percentage of nitrogen, and seems to possess much value as a source of fuel and fertilizer.

Camden County, N. C.—Holes G, H, and I, which were sunk half a mile apart along Dismal Swamp Canal, and half a mile to 1½ miles northwest of Lilly, Camden County, N. C., failed to show peat of commercial value. Muck averaging 3 feet in depth was found, but it was not sampled. These tests, however, do not prove that there is no peat in workable quantities in the county. The vegetation in the region consists chiefly of maples, sedges, grasses, canes, ferns, and mosses. Sphagnum moss suitable for surgical dressings is abundant, and it is reported that pure sphagnum covers many square miles in the territory west of Dismal Swamp Canal.

Other counties.—Large quantities of peat are said to occur in Perquimans and Pasquotank counties, N. C., but they were not examined for this report.

SOUTH CAROLINA.

Although peat occurs in marshes and swamps adjoining Peedee, Santee, and Combahee rivers and in salt marshes along the coast, notably in Georgetown and Horry counties, many of the deposits are small and shallow and contain a large proportion of inorganic impurities. According to Sloan,[57] the ash content of the peat where tested in the counties mentioned is about 29 per cent, which shows that it is of no value for fuel.

GEORGIA.

Peat is found near Pineora, Effingham County, in the Okefenokee Swamp, and at other places in the southeastern part of Georgia. The deposit near Pineora is reported to be about 600 acres in area and 5 feet deep and to be suitable for fertilizer.

FLORIDA.

General features.—Peat deposits are distributed over almost the entire State of Florida, and that State probably contains more peat than any other, except Minnesota and Wisconsin. The deposits that have been examined appear to contain 1,000,000,000 tons, and the Everglades, which have not been extensively tested, probably

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[57] Sloan, Earle, Catalogue of the mineral localities of South Carolina: South Carolina Geol. Survey Bull. 2, ser. 4, p. 362, 1908.

contain an equal quantity. The State is therefore believed to be capable of yielding 2,000,000,000 short tons of air-dried peat.

For the sake of convenience the deposits are roughly assigned to the following 14 regions, illustrated by Plate XVIII, and though these regions are largely geographic, the peat shows some differences in origin and quality. The data here given were taken in substance from a report by the Florida State Geological Survey.[58] For analyses of peats of Florida see pages 23–26.

West coast region.—The west coast region includes a belt of land a few miles wide along the western coast, which contains small quantities of good peat in depressions among sand dunes. Some peat is also found in the estuaries of Blackwater, Apalachicola, and other rivers, but these deposits contain so much inorganic material that they are of little economic value.

West pine-hill region.—The climatic and floral conditions in the west pine-hill region are favorable for the formation of peat, but the topography is generally unfavorable. However, some peat of fair quality is reported to occur in some of the Tyty swamps.

West limestone region.—The quantity of peat in the west limestone region is small.

Middle hammock region.—Because of the few streams and the thorough drainage of the basins in the middle hammock region it contains relatively little peat.

Lime-sink region.—The lime-sink region does not contain much peat.

Middle flatwood region.—Numerous deposits of shallow peat occur in the ponds throughout the middle flatwood region.

Gulf hammock region.—Large peat deposits occur in lakes, rivers, and estuaries in the Gulf hammock region. The best deposit thus far tested is that at Lake Panasoffkee, Sumter County, which contains peat 20 feet deep of good quality for fuel or fertilizer.

Lake region.—Thousands of small lakes containing extensive peat deposits occur throughout the lake region. In fact, peat of excellent quality is said to be found in nearly every square mile. The swamps and bogs are of different types, and consequently the peat varies in composition.

East flatwood region.—The east flatwood region contains extensive peat deposits in the estuary of St. Johns River. As the river is navigable, the peat could readily be transported to market. The predominant vegetation in this region consists of long-leaf and slash pine, saw palmetto, pond cypress, and sweet and black gum trees.

East coast region.—In a narrow region along the eastern coast of Florida from the northern boundary to Cape Florida, a distance of

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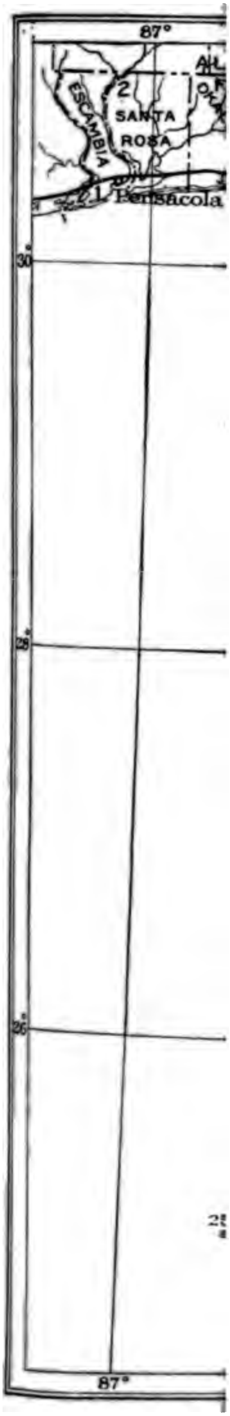
[58] Harper, R. M., Preliminary report on the peat deposits of Florida: Florida Geol. Survey Third Ann. Rept., pp. 197–375, 1910.


87°
2
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1
Pensacola
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26°
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ore than 350 miles, barrier beaches, sand dunes, and lagoons con-
ining fresh and salt water are common. Many of the fresh-water
goons contain good peat.

South flatwood region.—The south flatwood region embraces the
rthern part of the Everglades and contains one of the most exten-
ve peat deposits in the United States.

Miami limestone region.—The Miami limestone region, which in-
ides part of the Everglades, contains many peat deposits, most of
ich are of swamp and estuarine origin.

Coast prairie region.—The peat resources of the coast prairie region
e reported to be relatively scanty.

Key region.—The key region, though it is not a commercial source
peat fuel, is interesting because most of its peat was formed by the
composition of débris from mangrove trees.

OTHER STATES.

As shown on Plate I, peat occurs in areas in southern Delaware and
utheastern Maryland, but they were not examined for this report.

OTHER REGIONS.

GULF COAST.

Peat occurs in a narrow belt of land along the coast of Alabama,
ississippi, Louisiana, and Texas, but so far as the writers are aware,
e deposits have not been examined.

CALIFORNIA.

Although California contains several large deposits of impure
at and muck, areas of undrained land in that State are relatively
all compared with those of the States in the glacial and Atlantic
stal regions that contain the most notable deposits of peat. The
incipal deposits occur in Lower Klamath Lake, Siskiyou County,
the lower valleys of Sacramento and San Joaquin rivers, and in
s Angeles and Orange counties. Some peat is also found in San
rnardino County and in the marshes adjoining San Francisco
y and Salinas River. Many of the valley deposits, especially
se near Sacramento and Stockton, contain so much sand and silt
t has been deposited by the rivers and are so deeply buried by
draulic mining débris that they are of doubtful value for fuel,
t much of this peat contains a high percentage of nitrogen and
ld be advantageously used as a direct fertilizer or as an ingre-
nt of commercial fertilizers. The peat lands in the lower valleys
Sacramento and San Joaquin rivers are very fertile and bring
gh prices when sold for agricultural use.

The following excerpt[59] contains the best data available relating to the distribution and quantity of peat in California:

> The large undrained river valleys of California are overgrown by tule, duck weeds, cat-tails, and other plants, and should therefore contain peat deposits. The deepest deposits are believed to occur in the area extending from Carquinez Straits to Stockton and Riovista, embracing 12 townships, 432 square miles or 276,480 acres. The peat probably ranges from 6 to 80 feet in depth, or an average of 48 feet. The eastern part has been covered by débris from hydraulic mines, and in other portions the peat is somewhat sandy. Probably about one-half of the total area, or 138,240 acres contains peat. Of this area 60,000 acres are known to contain good peat to a depth of at least 6 feet. This tract is therefore estimated to be capable of yielding 72,000,000 short tons of air-dried peat. If the entire 188,240-acre tract contains peat 48 feet in average depth it should yield 1,188,864,000 tons, but it is probable that most of the material outside of the 60,000-acre tract is muck. It is unfortunate for the peat industry that this land is among the most valuable in California for agricultural purposes, as it is therefore questionable whether the peat would prove more valuable for fuel or fertilizer than for farming.

OREGON AND WASHINGTON.

The topography of Oregon and Washington is unfavorable for the accumulation of large deposits of peat. However, many small undrained areas adjoining lakes and rivers in the central and eastern parts of these States contain small peat beds, but it is doubtful whether they are of commercial extent.

Peat has been reported to occur in some of the lakes and river valleys of Cowlitz, King, Pierce, and Snohomish counties, Wash., but most of it is believed to be high in ash and unfit for fuel.

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[59] Requa, M. L., Bradley, F. W., and Stalder, W., Fuel resources of California: Commonwealth Club of San Francisco Trans., 1912.

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